AMERICAN RAILWAY SHOP SYSTEMS

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AMERICAN RAILWAY SHOP SYSTEMS

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PREFACE.

The aim in presenting this treatise on "American Railway Shop Systems" has been to collect, in convenient form for reference, general information as to the layout and leading characteristics of railway repair shops, particular attention being paid to establishing a special grouping and classification of shops as an aid to an intelligent analysis and understanding of the subject. Without clear distinctions as to the various classes of shops and shop layouts, discussions and opinions based on individual familiarity with one class of layouts will always be conflicting and confusing.

No general treatise on this subject has ever been published. The marked advance in shop methods during the last decade and especially the great demand during the last few years by railroad companies for improvements and new shops to meet the increasing necessity for better shop machinery and properly equipped shops to handle the repairs of the heavy power and rolling stock should cause a book on this subject [illegible] and operating [illegible] efficiency of the [illegible]

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CHAPTER I.

CLASSIFICATION AND GENERAL LAYOUT.

1.—GENERAL CLASSIFICATION.

In considering the general layout of a railroad shop system or discussing existing shops and methods, the most important point to keep clearly in mind is the distinctive features of shop systems, in other words, to establish a clear classification. If this is done, the entire subject can be handled and discussed systematically and valuable comparisons made.

Locomotive and car shops can be classed as manufacturing or repair plants. The Juniata shops of the Pennsylvania at Altoona is the only large railroad establishment in this country devoted exclusively to the building of locomotives. A number of railroads make all their freight cars, but the same shops are also used for car repairs. Generally speaking American railroad shops are primarily intended for repairs.

In this treatise the subject will be considered particularly from the standpoint of large railroad repair plants. Further, in citing examples of recent practice, the aim has been to include the principal new plants erected since about 1890 and to briefly refer to older prominent plants which have been remodeled or extended during the last few years.

Railroad repair shops can be grouped in three principal classes, according to their size and location, viz.:

(a.) Local Repair Shops, usually at roundhouses, for making emergency repairs.

(b.) Division or General Repair Shops at division or junction yards.

(c.) Main Repair Shops at some central point with reference to the whole railroad system or a grand division of the same.

On small roads general repair shops having all the characteristics of division shops on a larger road are classed and serve as the main shop. The above classification is only absolutely correct for a large road.

In regard to the class of repairs, railroad repair shops can be grouped as follows:

(a.) Locomotive repair shops.

(b.) Passenger car repair shops.

(c.) Freight car repair shops.

In small plants of a large railroad and in the main plants of a small road these departments, while occupying separate quarters and kept, more or less, distinct from each other, are frequently combined in one shop or in a closely connected set of buildings. On larger roads, however, the general tendency has been heretofore to establish large special shops for each class of work, or to have distinct sets of buildings grouped together and assigned to each class of work, with a clear distinction and separate control of the car and locomotive departments. The tendency to-day is more towards a closer connection of the car and locomotive branches of repair shops, due no doubt to the fact that these two branches are now generally merged and placed in charge of one official and the old separate departmental system abolished.

As a general proposition, it can be stated that the combination of locomotive and car shops in one plant, properly grouped, can be considered as good modern practice, where a suitable location and ample land and facilities are available.

There is no doubt that for heavy repairs to equipment the concentration of all such work in a large properly designed and equipped shop will be conducive to economy and speed of output. Whether it is desirable to carry this centralization scheme to such an extent as to possibly tie up the whole road in case of trouble with shop employees is a question that needs careful consideration. In the light of recent practice, railroad companies seem to prefer taking chances on the labor question and in the meanwhile derive all the benefits accruing from the shop concentration. Inquiry of a number of general motive power officers, on whose roads within recent years large central plants have been established, indicated that the labor question had been fully considered before adopting the centralization scheme, and that the benefits to be derived had outweighed the objections.

2.—SELECTION OF LOCATION.

The location of local repair shops and division general repair shops is indicated by the necessities and local conditions in each case.

The location of large main repair shops for the entire system or for a grand division of a very large road should be made with a view to obtaining a good central location convenient to the several parts of the main line and branches that are to be taken care of. This central location need not necessarily be the geographical center, but it should be near the traffic center; in other words, where the largest number of engines concentrate or where it is

most convenient for empty cars en route to be stopped for repairs.

The main source of supply of materials and the labor market are important elements. The cost of land and building materials and whether ample ground of suitable character and shape can be secured are important questions. The feature of State control of manufacturing plants and the local and State tax rates may also influence the location.

Assuming the general locality to have been selected, then the prime consideration is to obtain ample ground suitable for development not only for present needs but of sufficient size to allow for future expansion. Further points to consider are the character of the foundations, the drainage of surface water, sewerage and sub-drainage, water supply, etc.

3.—EVOLUTION OF GENERAL GROUND PLAN LAYOUTS OF SHOP SYSTEMS.

The earliest railroad shop systems consisted of one or more main buildings reached by tracks in the form of a yard approach, the tracks either running lengthwise through the building, which system is known as the longitudinal shop system, or with transverse dead end tracks in the building, known as the transverse or cross shop system.

The next step consisted in curtailing the space required for a yard approach by introducing a turntable for a limited number of tracks or a transfer table for a large number of shop tracks.

The development of overhead traveling cranes allowed the introduction of the longitudinal locomotive erecting shop in which there are three tracks, the middle one serving for communication, and the two outside tracks for

placing locomotives, two cranes being used to lift locomotives from the middle to the side track.

Similarly the introduction of overhead traveling cranes in cross locomotive erecting shops offered advantages in un-wheeling and re-wheeling a locomotive in place of using jacks, drop pits, or special staging with fixed hoists.

The most recent application of overhead traveling cranes in cross locomotive erecting shops consists in having one traveling crane heavy and high enough to lift the heaviest locomotive over other locomotives on the floor, in place of using a transfer table. This system was adopted by locomotive builders about 1890, but railroad companies did not make use of it until 1900. It is now in use at the locomotive erecting shops of the Philadelphia & Reading at Reading, Pa., of the Lake Shore & Michigan Southern at Collinwood, O., of the Pittsburgh & Lake Erie at McKees Rocks, Pa., and is also used in a modified form by the Pennsylvania at Altoona. It is now being installed by the Lehigh Valley at Sayre, Pa.

In regard to labor saving appliances around the shops for lifting heavy weights, the earlier installations used tackle and fixed cranes of various forms, also overhead trolleys, walking cranes and gantry cranes. The decade 1880 to 1890 might be classed as the educational period in demonstrating the advantages to be derived from pneumatic hoists and mechanical contrivances, and the decade from 1890 to 1900 as a similar educational period for bringing out the good and economical features of overhead traveling cranes, not only in the locomotive erecting shop, but also in the machine shop, boiler shop, heavy woodworking departments, and even outside the buildings in yards. To-day, a shop is not considered up-

to-date and equipped for economical work unless it has a full complement of overhead traveling cranes and pneumatic hoists throughout the shops and yards. It can also be reasonably predicted that conveying systems and electric or pneumatic switching engines will be gradually introduced extensively in the shop service.

In regard to the grouping of the buildings comprising a shop system, in the early layouts the buildings had to be set close together so as to be mechanically shaft driven from engines as centrally located as possible, thereby cramping the layout, limiting the designer, and, in large plants, introducing separate power stations for each group of buildings.

During the decade from 1880 to 1890 the system of rope driving was introduced to some extent and considered as the possible permanent solution of the question of reaching distant buildings from a central power station. Similarly pneumatic enthusiasts ventilated their doctrines freely, and a number of manufacturing plants and some isolated railroad shops were operated by pneumatic power. In general, the time from about 1885 to 1895 represents the period in which the application of electric power for shops, manufacturing, lighting and power plants made such wonderful strides that it is now generally acknowledged as being superior to all other forms of power for large shop plants, offering the greatest freedom in designing the layout and combining the source of all power for machinery, cranes, lighting, heating, ventilating, etc., in one central station.

While electric power supply is still in the course of development, it can be safely stated that, more particularly with the direct current installations, the state of the art, and the machinery and methods of application

have been well exploited, tested and standardized, and the machinery can be obtained in the open market.

Polyphase systems have been successfully used and a number introduced in large railroad shops, but this class of machines is still under the control of a small number of electric companies, and competition is not as vigorous as in the direct current systems. Nevertheless, the wide adaptability of the alternating current is being daily recognized, and the chances are that inside of the next five years it will make as marked advance for railroad power plants as the present outlook for its replacing in many cases the direct current in electric railway installations.

Reference should also be made to the favorable outlook for cheapening the power supply for shops by introducing steam turbines and gas engines, although in both of these systems the question of heating the shops must not be lost sight of, which with the steam engine is done very economically with the exhaust steam.

The tendency of the day is also to build heavier machine tools, adapted to higher speeds, with a larger range or variation of speed, and equipped with improved high-grade tool steels.

More attention is also being paid in recent years to giving more free working space around engines and machines, and also to provide room and systematic disposition and storing of dismantled parts.

From the above review of the evolution that has taken place in the general ground plan layout and equipment of shop systems, due to the introduction of improved handling methods, power and lighting supply, it is apparent that the older shop plants of the country are laboring under serious disadvantages, and that even a

number of comparatively new plants, built from 1888 to 1892, which were considered model show plants ten years ago, will have to be classed to-day as not strictly up-to-date.

Heavy business, prosperous times, the introduction of heavy engines and cars, the lowering of rates and hence the pressure to reduce unit cost of all shop operations, all tend to emphasize the necessity of a railroad company introducing the very best appliances and methods. Manufacturing companies are ten years ahead of the railroads in this respect, and, while manufacturing and repair work offer different problems in the detail conduct of the work, railroad companies will not lose by patterning after manufacturing plants, as far as introducing electric power, overhead cranes, up-to-date tools, and all labor-saving appliances.

For the last few years many railroad companies have been looking into the question of improving and enlarging their shop facilities to meet the increased demands. For a number of years following the railroad depression, about ten years ago, the companies did not make any important addition to their shop plants, and the absence of the regular yearly increment of shop improvements for a period of nearly ten years began to tell seriously.

Furthermore, the new heavy power and cars, introduced during recent years, are now beginning to be shopped for heavy repairs in increasing numbers, and it is becoming more apparent that the old shop facilities and methods are not fitted for this heavy work. This is a feature that the advocates for the introduction of heavy equipment did not foresee or take fully into account, the question having been treated largely from the transportation standpoint. Casual inquiry of shop fore-

men and men in detail charge of shops will usually not indicate that anything is wrong, as such men are noted for introducing "shop-kinks" and home-made appliances and contrivances for obviating to some extent the serious troubles occasioned by the new set of conditions and further are prone to remain in the same old rut. The general balance sheet and annual expense records of old shops, however, compared with the possible savings under modern methods and up-to-date tools and appliances, will tell the story and point the direction for additional economy.

Particular attention should be called to the feature that it is not only the saving in expense that should be aimed for, but one of the greatest benefits of an up-to-date shop plant is the increased speed with which equipment can be turned out and restored to service. This feature of a modern shop plant is generally overlooked or underrated.

The following conclusions of the Committee of the American Railway Master Mechanics' Association in 1894, on the subject, "Cost of Maintaining Locomotives," are very pertinent:

"The importance of centralizing the work of heavy repairs in one or more large shops on the system, well equipped for doing such work economically, should not be lost sight of. Heavy repairs conducted in small and imperfectly equipped shops not only cost more than at the main shops, but require more time and keep the engine out of service for a longer period than is necessary.

"In conducting repair work two important considerations should always be kept in mind—the actual cost of the repairs, and the time the engine is kept out of service in making them."

4.—CLASSIFICATION OF GENERAL RAILROAD REPAIR SHOP LAYOUTS.

Large general repair shops or main repair shops combining the work of repairing locomotives and cars can be classified, according to the leading characteristics of the ground plan layout and the grouping of the principal departments, as follows:

A.—Complete transfer table layout.

(a.) All departments combined along one transfer table.

(b.) The various departments grouped along separate transfer tables.

B.—Combination of transfer table and longitudinal layout.

(a.) Longitudinal freight car shop; all other departments transfer tables.

(b.) Longitudinal locomotive erecting shop, all other departments separate transfer tables.

c.) Longitudinal locomotive erecting shop, longitudinal freight car shop, and transfer table passenger car shop.

C.—Combination of transfer table and a cross locomotive erecting shop with traversing crane for lifting engines over each other.

(a.) Cross locomotive erecting shop with crane for lifting engines over each other, otherwise transfer tables for all other departments.

b.) Cross locomotive erecting shop with crane for lifting engines over each other, passenger car shop with transfer table, and longitudinal freight car shop.

D.—Layouts without transfer tables.

(a.) All longitudinal layout.

(b.) Cross locomotive erecting shop with crane for lifting engines over each other, otherwise longitudinal layout.

5.—CLASSIFICATION OF LOCOMOTIVE REPAIR SHOPS.

Locomotive repair shops can be classified, according to the ground plan layout and method of transferring locomotives into and out of the building, as follows:

A.—Cross track layout.

(a.) With yard approach.

(b.) With one transfer table.

(c.) With two transfer tables, one for the erecting shop and one for the boiler shop.

(d.) Cross erecting shop with traversing crane for lifting engines over each other.

B.—Longitudinal track layout.

(a.) All longitudinal layout.

(b.) Longitudinal layout in combination with a transfer table service at one end.

Cross erecting locomotive shops with cranes for lifting engines over each other set with the pits in the house at right angles to the general direction of the yard tracks have to be provided with a turn-table for handling locomotives in and out of the house.

6.—CLASSIFICATION OF PASSENGER CAR REPAIR SHOPS.

There is no information at hand that any railroad company in this country maintains a separate large passenger car repair plant. The shops for taking care of passenger car equipment are generally connected with special car shops for passenger and freight equipment or form part of a general repair shop plant.

Omitting small older special designs, influenced by local conditions, passenger car repair shops can be classified as follows:

A.—Cross track layout with transfer table.
B.—Longitudinal track layout.

7.—CLASSIFICATION OF FREIGHT CAR REPAIR SHOPS.

There are a number of separate railroad plants for freight car repairs in this country, but frequently the repairs to passenger and freight equipment are combined in a separate large plant or more generally form part of a general repair shop plant.

Omitting special small designs, influenced by local conditions, freight car repair shops can be classified as follows:

A.—Cross tracks served by transfer table.
B.—Cross tracks with yard approach.
C.—Longitudinal track layout with yard approach at one end of main building and transfer table at other end.
D.—Longitudinal layout with track approach.
(a.) With track approach at one end of main building.
(b.) With track approach at both ends of main building.

Most of the plants with transfer tables have stub tracks or a track approach on the other side of the car shop, or a system of long parallel tracks at some part of the yard, for light freight car repairs. In longitudinal layouts most of the plants use the tracks on the approaches to the main freight car building for repair work in the open and further usually provide a series of long tracks, parallel with the main shop buildings and its approaches, for light repairs.

8.—GENERAL TENDENCY OF LAYOUT OF RAILROAD REPAIR SHOP SYSTEMS.

Reviewing critically the classification of railroad repair shop systems, and eliminating small plants more in

the nature of division shops, and also giving consideration to the local conditions influencing the choice of certain designs, it can be stated as a broad proposition, based upon the best modern practice, wherever the conditions offer the designer practically a free scope, that the following designs are preferred for large railroad repair shops, viz.:

Freight car, heavy repairs.—Longitudinal main shop with track approaches at each end and in some cases with auxiliary transfer table at one end of the shop.

Freight car, light repairs.—A series of long parallel tracks connected up with the yard at each end and preferably alongside of car repair shop.

Passenger car repairs.—Transfer table service.

Locomotive erecting shop.—Cross tracks and heavy traversing crane for lifting locomotives over each other; also longitudinal track layout.

For a small division repair shop of a large road or for a general repair shop of a small road, with a maximum stall capacity of about 15 locomotives, the so-called "Division Shop" system of serving all departments by one transfer table is preferred.

9.—GENERAL TENDENCY OF THE GROUPING AND CONSTRUCTION OF SHOP BUILDINGS.

In large railroad general repair shops or main repair shops of a large road, the general tendency is to group the several departments and then to concentrate the principal sub-departments or special branches of work belonging to each group in one large building or in a series of closely connected buildings.

There are certain classes of work common to more than one department and the special buildings for these should be as convenient as possible to the department

groups they serve. The storehouse and power plant should receive a central location.

The sub-departments in each group should be arranged and placed so as to reduce unproductive travel of men and materials, and also to follow, as far as practicable, the sequence of the main operations from beginning to finish. This cannot be carried to as fine a point in repair shops as in contract manufacturing shops. In the latter all movements are towards the assembled car or piece of machinery, while in repair shops the movements are in both directions, from the dismantled engine or car to the various sub-departments and then back to be fitted into place.

Owing to the weight and bulk of the shop output, viz., locomotives and cars, it is evident that one-story structures are preferable throughout, although certain small work and the storage of light materials can be placed in upper stories. The tendency is towards large one-story buildings with the sub-departments in one building, and in many cases with imaginary division lines only and not regularly partitioned off spaces for the various sub-departments.

The principal points to consider in laying out a shop building are:

1. Locate the various sub-departments in proper relation to each other so as to avoid unproductive travel of men and material.
2. Establish the proportionate space required for each sub-department so as to correspond to the total shop output.
3. Provide proper communication and transfer methods between the various sub-departments and the entire shop system, yard, storehouse, etc.
4. Feasibility of overflow from one sub-department to another so as to make the sub-division elastic and capable of accommodating changed conditions in the future, or correct errors in the original proportioning of space.

5. Ample free floor space around machines and pits to give greater freedom in working and chance to store dismantled or new parts, material waiting to be worked up, or finished material.

6. Ample passageways and ease of supervision and observation of the various working forces and operations.

7. Ample and uniform lighting, day or night, and avoidance of shadows.

8. Efficient heating and good ventilation.

9. Proper sanitary appliances, sewerage, toilets, lavatories, lockers, etc.

10. Water supply and fire protection service.

11. Selection of class of materials to suit the purposes of each building and such degree of fireproofing as deemed advisable.

12. The grouping of the buildings and class of construction should not conflict with fire insurance regulations.

13. The exterior of the buildings should present a neat and substantial appearance, in accord with their character. Architectural embellishments purely for the sake of an assumed æsthetic effect are out of place in a manufacturing plant.

14. Selection and location of machinery, determination of class of power and method of driving.

15. Auxiliary features such as pneumatic power supply and appliances, hot water, testing plants, smoke removal at forges, locomotive testing pits, etc.

16. The buildings and principal facilities should be on the basis of the service requirements at the time of the completion of the shop system and with a reasonable allowance for the probable yearly increase of the equipment for a number of years thereafter, so that the question of further extensions would not have to be considered for a period of about ten years after placing the new plant in operation.

17. Ample provision for possible future extensions of the plant.

In addition to the direct economy due to a well-designed shop and an up-to-date equipment, stress should be laid on the influences of a shop with ample facilities and space, well lighted, ventilated, heated, clean, etc., on the health, habits and disposition of the workmen.

As stated above, the tendency in railroad shop construction is to erect very large single-story buildings with few dividing walls. Such a building is proportionately cheaper than a number of smaller buildings covering the same total floor area, provided the roof spans are not excessive and column supports are introduced. The result gives a large airy shop with great freedom for observation and control of operations, and an elastic division of the sub-departments. The principal special structural features to take care of are the necessary disposition of the roof water, the arrangement of side windows and top lights, so as to give good and uniform light throughout the interior, and the heating. Otherwise there is nothing special or unusual. If electric power is used, the greatest freedom in locating and spacing machinery can be observed and distance is not a factor.

An objection is sometimes made to large shop buildings or the duplication of certain facilities (such as two erecting shops separated by a machine shop) that the supervision of the work is made more difficult than if the various sub-departments are grouped in separate buildings. There is no serious objection on this score in very large shops. A number of large shops, notably manufacturing concerns, have actually introduced the so-called "unit-system" purposely, as one man cannot take charge of a large plant and it is well to have his assistants placed in charge of a certain unit of the plant. At the McCormick Reaper Works, Chicago, a foundry was recently built 1,200 ft. long, divided into three units or separate buildings 400 ft. long. At West Allis the Allis-Chalmers Works will have 12 wing buildings, each 575 ft. x 122 ft., all leading into the nearly one-half mile long main erecting shop, divided into four groups of three

wings each. Each group will be in charge of a separate foreman with assistant foremen in each wing. Similarly the one-half mile long erecting shop and the one-half mile long foundry will be sub-divided and placed in charge of separate men.

As indicative of the tendency of modern practice to erect large main shop buildings, and also so as to give some idea of the comparative size of modern plants and of several well-known older railroad shop layouts, it will be desirable to present the following data on this subject.

Pennsylvania, Locomotive Repair Shops, Altoona, Pa. Old shops remodeled in 1902. The old erecting and machine shops covered a space of 412′ x 330′, or 2.6 acres and 0.4 acre interior court yard, or a total of 3.0 acres. The transfer table, between the erecting and machine shops on one side and the blacksmith, wheel, boiler and tank shops on the other side, has been removed and a traveling crane introduced, which is to be covered over, for traversing locomotives. The intention is eventually to roof over the narrow court yard between the erecting and machine shops. This will give one building occupying practically a space 820′ x 330′, or 6.2 acres. As there are some small buildings in one corner of the above space detached from the main buildings, the actual size of the one main building under cover will be about 5 acres.

New York Central, Locomotive Repair Shops, Depew, N. Y. Built, 1892. Erecting pits, 48. Erecting, machine and blacksmith shops under one roof, 2.9 acres. All buildings, 4.6 acres.

Central of New Jersey, Elizabethport, N. J. General Repair Shops. Built, 1901. Erecting, machine and boiler shops under one roof, 150′ x 700′, or 2.4 acres. All buildings about 8 acres. Total ground, 60 acres.

Chicago and Northwestern, Kinzie Street, Chicago. General Repair Shops. Old shops. All buildings about 16 acres.

Illinois Central Ry., Burnside, Chicago. General Repair Shops. Built, 1892. All buildings about 11 acres. Total ground, 160 acres.

Boston and Maine, Concord, N. H. General Repair Shops. Built, 1898. Erecting shops. 14 engines. All buildings, 4.63 acres. Ground occupied, 26 acres.

Philadelphia and Reading, Reading, Pa. Main Locomotive Repair Shops. Built, 1901. Erecting and machine shop, 70 erecting pits, 200' x 740', or 3.4 acres. The store house, boiler, smith and forge shops are all connected and join on to the erecting and machine shop, making six sub-departments, covering 5.5 acres, with connected roofs. All buildings, including foundry, give about 8 acres floor space.

Lake Shore and Michigan Southern, Collinwood, O. Built, 1902. Main Locomotive Repair Shop with erecting, machine and boiler shops under one roof; 24 pits in erecting shop, 245' x 530', or 3 acres under one roof. All buildings of locomotive department give about 4.5 acres floor space. All buildings of the entire development for locomotives and cars will cover about 8 acres, when completed.

Pittsburgh and Lake Erie, McKees Rocks, Pa. Built in 1902. Erecting shop, 24 pits, and machine shop in one building, 175' x 540', or 2.2 acres. All buildings connected with locomotive department about 4 acres. All buildings of the entire development for locomotives and cars, about 10 acres.

Locomotive Shops, Norwich, England. Erecting shop, 118' x 1,520', or 4 acres. All buildings, about 13½ acres. Land occupied, 85 acres.

General Railroad Repair and Manufacturing Shops, Crewe, England. All buildings, 36 acres. Land occupied, 116 acres.

British Westinghouse Electric Co., Manchester, England. Built, 1902. Machine shop, 487' x 900', or 9 acres, under one roof.

American Car & Foundry Company, Berwick, Pa. Built, 1902. Main car shop, 730' x 185', or 3.1 acres.

Westinghouse Electric Co., East Pittsburgh. Main building under one roof, about 15 acres. New building recently erected, about 230' x 1,700', or about 9 acres, under one roof.

American Bridge Company, new shops at Economy, Pa., 1902. Main shop building, 270' x 780', or about 5 acres.

Commonwealth Steel Co., Granite City, Ill. New plant, 1902. Main building about 3 acres.

New York Shipbuilding Co., Camden, N. J. Main building, 200' x 900', or about 4 acres, with a series of large connecting wing buildings. There are 22 acres of buildings, the larger amount being under one continuous connected roof construction.

Bethlehem Steel Works, South Bethlehem, Pa. Main machine shop, 117' x 1,375', or about 3.7 acres.

Stanley Electric Manufacturing Co., Pittsfield, Mass., 1901. Main building, 220' x 500', or 2.3 acres.

United Electric Street Railway, Repair Shops, Baltimore, Md. Two main buildings, each 370' x 480', or 4.1 acres each. There is a street between the buildings, which otherwise would, no doubt, have been combined, making one building with about 8 acres, under one roof.

Schoen Pressed Steel Co., Pittsburgh, Pa. Car erecting shop, 120' x 600', or 1.7 acres.

Howard Axle Works, Pittsburgh, Pa. Main building, 100' x 1,000', or 2.3 acres.

Allis-Chalmers Machine Shops, West Allis, Milwaukee, Wis. New plant. The buildings in use cover about 14 acres. The main shop building under one series of connected roofs will cover 28 acres. The foundry building will cover 11½ acres. The full future development scheme covers a total of 45 acres of buildings. The foundry and erecting shop will each be nearly one-half mile long.

Standard Steel Car Co., Butler, Pa., 1902. Main shop, 240' x 1,600', or 9 acres.

Madison Car Works, Madison, Ill. Main shop, 165' x 916', or 3.6 acres. Machine and blacksmith shop, 106' x 725'. Foundry, 126' x 652'. Paint shop, 125' x 550'. All buildings about 10 acres.

Chicago and Rock Island, East Moline, Ill., 1903. Erecting, machine and boiler shops in one building, 276' 8" x 860' 2", or 5.46 acres, in one building.

Lehigh Valley, Sayre, Pa., 1903. Erecting, machine and boiler shops in one building, 366' 3" x 748' 10", or 6.3 acres, in one building.

The above data, while fragmentary and incomplete, is valuable as indicating that the concentration of the principal sub-departments of a shop in one very large main building is representative of modern practice.

CHAPTER II.

GENERAL REPAIR SHOPS.

1.—EXAMPLES OF GENERAL REPAIR SHOP LAYOUTS.

The following examples of well-known or recently built railroad general repair shops, grouped on the basis of the classification previously outlined, will serve to indicate in detail the tendency of modern practice. In drawing conclusions from the list due regard must be paid to the fact that in many cases local conditions controlled the selection of the design in certain details and further that old shops, even if remodeled, are not absolutely representative of best modern practice.

In the list, the approximate year of construction or completion of the plant is given to indicate the period to which the design belongs.

A:—COMPLETE TRANSFER TABLE LAYOUT.

a.—All departments combined along one transfer table:

Ohio and Mississippi, Washington, Ind., 1889.

Louisville, New Albany and Chicago, Lafayette, Ind., 1895.

Chicago Great Western, Oelwein, Iowa, 1899.

Colorado Southern, Denver, Col., 1901.

Chicago, Burlington and Quincy (Hannibal and St. Joseph), Hannibal, Mo., 1901.

Wisconsin Central, Fond du Lac, Wis., 1901.

Fort Worth and Denver City, Childress, Tex., 1902.

Oregon Short Line, Pocatello, Idaho, 1902.

Southern Pacific, East Los Angeles, Cal., 1903.

b.—The various departments grouped along separate transfer tables:

Pennsylvania, Meadows Shops, Jersey City, N. J. Old shops; remodeled 1902.

Chicago and Northwestern, Kinzie Street, Chicago. Old shops (before extension in 1901).

Pennsylvania and Eastern, Urbana, Ill., 1897.

Southern California, San Bernardino, Cal. Old shops; extended 1902.

New York Central, West Albany, N. Y. Old shops; extended 1902.

B :—COMBINATION OF TRANSFER TABLE AND LONGITUDINAL LAYOUT.

a.—Longitudinal freight car shop, all other departments transfer tables:

Nashville, Chattanooga and St. Louis, Nashville, Tenn., 1890.

Northern Pacific, Edison, Tacoma, Wash., 1891.

Illinois Central, Burnside, Chicago, 1892.

East Tennessee, Virginia and Georgia, Knoxville, Tenn., 1893.

Cleveland, Cincinnati, Chicago and St. Louis, Wabash, Ind., 1896. (No special passenger car department.)

Chicago and Northwestern, Kinzie Street, Chicago. Old shops; extended 1901 by building new longitudinal freight car repair shop.

Chicago and Alton, Bloomington, Ill. Old shops, extended 1901.

St. Louis, Iron Mountain and Southern, Baring Cross, Kan., 1901.

Chicago, Milwaukee and St. Paul, West Milwaukee, Wis. Old shops, extended 1902.

New York Central, Oak Grove, Pa., 1902. (No passenger car department.)

Southern, Sheffield, Ala., 1902.

Minneapolis and St. Louis, Cedar Lake, Minneapolis, Minn. Old shops, extended 1902.

b.—Longitudinal locomotive erecting shop, all other departments transfer tables:

Boston and Maine, Concord, N. H., 1897.

Union Pacific, Omaha, Neb. Old shops, extended 1902.

Penn. Lines, Southwest System, Columbus, O. Old shops, remodeled 1902.

c.—Longitudinal locomotive erecting shop, longitudinal freight car shop, and transfer table passenger car shop:

Central of New Jersey, Elizabethport, N. J., 1901. Longitudinal erecting shop connects with transfer table.

Atchison, Topeka and Santa Fe, Topeka, Kan. Old shops, extended 1902.

Canadian Pacific, Montreal, Can., 1902.

C:—COMBINATION OF TRANSFER TABLE AND A CROSS LOCOMOTIVE ERECTING SHOP WITH TRAVERSING CRANE FOR LIFTING ENGINES OVER EACH OTHER.

a.—Cross locomotive erecting shop with crane for lifting engines over each other, otherwise transfer tables for all other departments:

Lake Shore and Michigan Southern, Collinwood, O., 1902.

b.—Cross locomotive erecting shop with crane for lifting engines over each other, passenger car shop with transfer table, and longitudinal freight car shop:

Lehigh Valley, Sayre, Pa. Old shops, extended 1903.

D:—LAYOUTS WITHOUT TRANSFER TABLES.

a.—All Longitudinal layout:

Norfolk and Western, Roanoke, Va. Old shops, remodeled 1901.
Mexican Central, Aguas Calientes, Mex., 1902.

b.—Cross locomotive erecting shop with traversing crane for lifting engines over each other, otherwise longitudinal layout:

Pittsburgh and Lake Erie, McKees Rocks, Pittsburgh, Pa., 1902.

2.—LAYOUT OF GENERAL REPAIR SHOPS.

There is no general rule that can be prescribed for the layout of general repair shops, excepting that for small shops in the nature of "division repair shops," even if classed on a small road as main repair shops, the preferred design is no doubt the system with one transfer table serving all departments. This system is very compact and well adapted for small shops. It does not seem to have been used in any shop layout with more than 15 locomotive erecting pits, indeed, most of the examples have from 10 to 15 locomotive pits, and the boiler shop, passenger and freight car departments are correspondingly small.

For large general repair shops the preferred system is to group separately the buildings and facilities belonging to each of the three principal classes of work, viz.: locomotives, passenger cars and freight cars. Local conditions and individual opinions control the layouts.

In some cases all three groups are laid out on the longitudinal plan, in other cases they are all concentrated on separate transfer tables. The bulk of the modern layouts tend towards differentiation of the cross and longitudinal systems according to the best results to be obtained for the work in each department and the layout of the available land.

It can be stated, however, that for large shop layouts the preferred systems are: For light freight car repairs, long parallel tracks connected at each end to yard leaders. For heavy freight car repairs, longitudinal buildings with tracks extending some distance each way from the building and connected up at each end to yard leaders; where the plant is large, an auxiliary transfer table at the shop is introduced for lateral movement. For passenger car repairs, transfer table service. For locomotive erecting shops, cross tracks with heavy traversing crane for lifting locomotives over each other; also the system of longitudinal tracks. The heaviest modern plants, however, tend towards the system of cross locomotive erecting shop with heavy traversing cranes for lifting engines over each other; although a number of large plants have been recently built with longitudinal locomotive erecting shops.

CHAPTER III.

LOCOMOTIVE REPAIR SHOPS.

1.—EXAMPLES OF LOCOMOTIVE REPAIR SHOP LAYOUTS.

The following examples of well-known or recently built locomotive repair shops, grouped on the basis of the classification adopted above, will indicate the trend of recent practice.

A:—CROSS TRACK LAYOUT.

a.—With yard approach:

Generally at old and small shops.

b.—With one transfer table:

1.—Examples of separate locomotive plants:

C. C. C. & St. L., Bellefontaine, O., 1893.

Pennsylvania, Altoona, Pa. Old locomotive repair shops. (Old layout with transfer table has been changed recently to overhead crane transfer service in place of transfer table.)

Great Northern, Dale Street, St. Paul, Minn., 1902.

Chicago, St. Paul, Minneapolis and Omaha, Sioux City, Iowa, 1903.

2.—Examples of locomotive shops at general repair plants:

At all general repair shops where the one transfer table serves all the departments, and hence, transfer table a necessity; recent examples:

Lafayette, Ind., 1895.

Oelwein, Iowa, 1899.

Denver, Col., 1901.

Hannibal, Mo., 1901.

Fond du Lac, Wis., 1901.

Pocatello, Idaho, 1902.

East Los Angeles, Cal., 1903.

At the following general repair shops where all departments are grouped and served by separate transfer tables:

Chicago and Northwestern, Kinzie Street, Chicago. Old shop layout.

Pennsylvania, Meadows Shops, Jersey City, N. J. Old shops, remodeled 1902. Roof of locomotive erecting shop raised and 125-ton crane used for unwheeling engines on pits.

Southern California, San Bernardino, Cal. Old shops, extended 1902.

At the following general repair shops where all departments have transfer tables, excepting longitudinal freight car shop:

Nashville, Tenn., 1890.

Tacoma, Wash., 1891.

Burnside, Chicago, 1892.

Knoxville, Tenn., 1893.

Wabash, Ind., 1896.

Bloomington, Ill. Old shops, extended 1901.

Chicago, Milwaukee and St. Paul, West Milwaukee, Wis. Old shops, extended 1902.

Kinzie Street, Chicago. Old shops, extended 1901.

Baring Cross, Kan., 1901.

Sheffield, Ala., 1902.

Cedar Lake, Minneapolis. Old shops, extended 1902.

New York Central, Oak Grove, Pa., 1902.

c.—With two transfer tables, one for erecting shop and one for boiler shop:

New York Central, Depew, N. Y., 1892.

Chicago, St. Paul, Minneapolis and Omaha, St. Paul, Minn. Old shops, extended 1902.

d.—Cross erecting shop with traversing crane for lifting engines over each other:

1. Examples of railroad shops:

Philadelphia and Reading, Reading, Pa., 1901.

Lake Shore and Michigan Southern, Collinwood, O., 1902.

Pittsburgh and Lake Erie, McKees Rocks, Pittsburgh, Pa., 1902.

Lehigh Valley, Sayre, Pa., 1903.

Great North of Scotland, Inverurie, Scotland, England, 1900.

2.—Examples of locomotive builders' shops:

Baldwin Locomotive Works, Philadelphia, Pa., 1890.

Richmond Locomotive Works, Richmond, Va., 1902.

Rogers Locomotive Works, Paterson, N. J. Extension 1902.

Brooks' Locomotive Works, Dunkirk, N. Y., 1899.

3.—A modification of this system is in use at the old repair machine shops of the Pennsylvania at Altoona, Pa. The old transfer table, serving the erecting shops and machine shop on one side and serving the boiler, wheel and blacksmith shops on the other side, has been replaced by an overhead traveling crane for traversing engines going to or from the erecting shop or boiler shop. The difference consists in the diminished height of the lift as the moving engine is simply lifted free of the rails.

B:—LONGITUDINAL TRACK LAYOUT.

a.—All longitudinal layout:

1. Examples of separate locomotive plants:

Pennsylvania, Juniata shops, Altoona, Pa. Manufacturing plant, 1890. Extended 1903.

Penn. Lines, Northwest System, Fort Wayne, Ind. Old shops, remodeled 1903, and longitudinal erecting shop added.

2. Examples of locomotive shop at general repair plants:

Norfolk and Western, Roanoke, Va. Old shops, remodeled 1901.

Baltimore and Ohio, Baltimore, Md. Longitudinal erecting shop, 80 engines, added in 1896.

Boston and Maine, Concord, N. H., 1897.

Union Pacific, Omaha, Neb. Old shops, extended 1902.

Penn. Lines, Southwest System, Columbus, O. Old shops, remodeled 1902; longitudinal locomotive erecting shop added.

Mexican Central, Aguas Calientes, Mex., 1902.

Atchison, Topeka and Santa Fe, Topeka, Kan. Old shops, extended 1902.

Canadian Pacific, Montreal, Can., 1902.

Chicago and Rock Island, East Moline, Ill., 1903.

b.—Longitudinal layout in combination with a transfer table service at one end:

Central of New Jersey, Elizabethport, N. J. Transfer table at one end, 1901.

Buffalo, Rochester and Pittsburgh, Dubois, Pa. At present stub tracks at one end of building, but plan provides for a future transfer table, 1901.

Lancashire and Yorkshire, Horwich, England. Building 1,520 feet long, with two transfer tables running across the interior of the shop, 1887 to 1892.

Michigan Central, Jackson, Mich. Old shops, extended 1902.

2.—GROUPING OF DEPARTMENTS IN A LOCOMOTIVE REPAIR SHOP.

The principal departments for locomotive repairs are the erecting shop, machine shop and boiler shop. These are usually grouped together and form the "main locomotive shop," either in one building or in closely connected buildings.

Further, there has to be provided a blacksmith shop. These four shops, viz.: erecting shop, machine shop, boiler shop and blacksmith shop, form the main sub-departments.

In addition there are the following shops, or sub-departments, viz.: Wheel shop, tank shop, hammer shop for heavy forging, flange shop, flue shop, which, in some cases, are provided for in the boiler and blacksmith shop, and in other cases are in separate buildings.

Provision has also to be made for iron and castings storage sheds, scrap bins or scrap yard, storehouse, tool room, carpenter shop, pattern shop, etc. Also offices, power plant, oil house, etc., usually provided for joint use of car and locomotive departments. In some cases a special small paint shop is provided for the locomotive department. In special cases, foundries for iron, brass or copper are added.

It is desirable to have the roundhouse close to and connected by a track with the locomotive shop, so that light engine repairs in the roundhouse can be made from the main shop or locomotives easily transferred from the roundhouse to shops.

The machine shop is practically in all designs in the same building as the erecting shop, and is placed parallel to the pits in a longitudinal shop or parallel to the row of pits in a cross shop. There are few variations from this rule in the modern layouts.

The boiler shop in recent large installations is part of the main locomotive shop and arranged so that boilers after being un-wheeled can be readily transferred to the boiler shop, either by overhead cranes or on push cars. At transfer table layouts the boiler shop is frequently on the opposite side of the table from the main locomotive shop. The relation of the boiler shop to the erecting shop, with reference to transferring boilers by cranes, is one of the first points that should be considered in any contemplated layout.

The disposition and handling of the wheels, after being removed from the locomotive, on their way to and from the machine shop is one of the most important points to consider.

The storage for dismantled parts of the engine has to be provided. This is sometimes done on racks between the pits, in outside yards, in yards under cover, or in floor pits.

No particular rule can be given as to the proper location of the blacksmith shop and minor buildings of the plant, as their location is usually governed by local conditions, but they should be placed with reference to the least handling of materials and avoidance of unproductive travel.

3.—LONGITUDINAL VS. CROSS ERECTING SHOPS.

The question of whether to adopt a longitudinal or a cross erecting shop has been the source of more discussion than any other subject connected with the layout of railroad locomotive shops.

The first requisite for an intelligent analysis of the subject is to settle what class or size shop is under consideration. It should be remembered that a cross shop,

owing to the development of the overhead crane, does not necessarily mean that a transfer table must be used, as heavy overhead traversing cranes for transferring engines inside the buildings are being extensively used at large plants.

In a division repair shop, or general repair shop of a small road, there seems no question but that a transfer table (especially in southern sections of the country), introduced as the main feature of the entire shop layout, should be used in connection with a cross erecting shop. The system is compact and all departments are brought into communication with each other by means of the one transfer table. The best modern practice provides a comparatively light overhead crane in the erecting shop for assisting in lifting heavy parts and transferring wheels. In some cases the crane is made heavy enough to transfer boilers and thus eliminates jacking, special lifting staging, drop pits or trucking of boilers.

As indicated above, in small general repair shop layouts, where a transfer table forms the leading feature of the plant, the use of a transfer table for the erecting shop becomes a practical necessity and its use at such plants is not a leading argument for or against a transfer table in cross shops, as the plant is probably too small to warrant a heavy overhead crane for lifting engines over each other or a longitudinal building not in harmony with the whole layout. These transfer table cross shops are usually small, as otherwise the one transfer table would be too heavily taxed, as it has to serve all the departments of the plant.

At general repair shops, where the one transfer table serves all departments, the number of erecting pits at shops, built since 1895, are as follows: Lafayette, Ind., 9; Oelwein, Iowa, 15; Denver, Col.,

10; Hannibal, Mo., 10; Fond du Lac, Wis., 15, and Pocatello, Idaho, 10.

At shops, where one transfer table serves the locomotive department only, the number of erecting pits are as follows:

Old Shop Layouts—Illinois Central, Burnside, Chicago, Ill., 25, with possible extension to 35 pits; Nashville, Tenn., 10; Tacoma, Wash., 11; St. Paul, Minn., 15; Bloomington, Ill., 18; Lehigh Valley, Sayre, Pa., 17; Lehigh Valley, Packerton, Pa., 11; Kinzie Street, Chicago, Ill., 25; West Milwaukee, Wis., 18, extended in 1902 to 25.

New Shop Layouts—Baring Cross, Ark., 15; Knoxville, Tenn., 16; Wabash, Ind., 7, with possible extension to 25 pits; Cedar Lake, Minn., 10; Oak Grove, Pa., 19, with possible extension to 25 pits; Great Northern, St. Paul, Minn., 25; Sioux City, Iowa, 8 pits.

Further—New York Central at Depew, N. Y., 48 pits.

It will be noted that the largest erecting shop, where one transfer table serves all departments of a general repair shop, has only 15 erecting pits, and, where one table is used only for the locomotive department, the number of erecting pits is limited to 25, excepting the New York Central shops at Depew, where there are 48. The Kinzie Street layout, at Chicago, was adopted about thirty years ago, and the subsequent enlargement to 25 pits had to follow the original scheme.

The only arguments that can be drawn from recent current practice in favor of a transfer table for large erecting shops are found in the fact that at the Burnside shops of the Illinois Central, at Chicago, a new plant was laid out with 25 pits in 1892, with provision for extension to a possible total of about 35 pits; that a new plant at St. Paul with 25 pits was built in 1902; and, further, that at Depew, built in 1892, there are 48 pits.

The layout at Depew differs from the others in that there are two erecting shops, one on each side of the

table with 24 pits each, and there is an additional transfer table for the boiler house service, whereas at all other shops considered the one transfer table serves erecting and boiler shops.

It seems, therefore, correct to draw the conclusion that in current practice a transfer table, serving only a locomotive shop, is limited to about 25 erecting pits, with the possible extension to 35 pits at Burnside, and the special layout for 48 pits at Depew with the auxiliary table for the boiler shop.

This analysis of transfer table service at locomotive shops has been deemed advisable so as to clear the ground for a free discussion of longitudinal or cross shops for large plants. Advocates of the longitudinal layout generally present the objectionable feature of transfer tables as an argument against cross shops, but the above analysis indicates that transfer tables are used more generally in comparatively small plants.

The objectionable features connected with transfer tables are that they take up valuable space, introduce a pit or obstruction between the various buildings, fill up with snow in winter in northern climates unless covered over, require many large doors in the side of the building, which necessitate constant repairs, cut off light, produce drafts and make the building harder to heat in winter.

The advantages of transfer tables for small shops are that they offer a very compact and neat layout and a handy and economical method of connecting all departments without lost space in track approaches and yard developments. They further allow a low building. Cross tracks in the main erecting shop allow the machine shop to be directly in the rear of the pits, which is undoubtedly the preferred position.

The tendency is to introduce a light traveling crane in cross erecting shops. In some cases the crane is made heavy enough to serve in lifting and transferring boilers. The longitudinal shop advocates point to the expense of the combination of crane and transfer table and consider it preferable to have two cranes in the house and no transfer table. In both cases two men are required. The expense will vary one way or the other dependent on the crane capacities and spans. The decision will depend on the general conditions and particularly on whether the transfer table is the controlling element of the entire shop layout.

The main question at issue for large erecting shops is longitudinal shop vs. cross shop with heavy traversing crane. In other words, the above analysis has shown that transfer tables are evidently used mainly for small plants, and the question for discussion in such case narrows itself down to a comparison of modern practice and the relative merits of longitudinal shops as compared with cross shops equipped with heavy overhead crane for traversing engines in the shop above other engines standing on the pits.

In building a shop the main feature is to design it so as to offer the cheapest possible operating methods and to facilitate the shop work so as to get engines out of the shop quickly. This is more important than comparatively petty questions as to whether one or the other system gives less height of building, or occupies less floor space, etc. In other words, the problem must be sized up from the practical operating standpoint and not absolutely as a question of first cost. It is more important to have first-class arrangements for stripping engines quickly, space for taking out flues, caring for dis-

mantled parts, transferring boilers and wheels back and forth quickly, clear passageways, freedom of transfer to and from the machine shop and no lost motion generally, than to save a comparatively insignificant sum at the start compared with subsequent steady losses in operation and delayed equipment for years afterwards. The watchword of to-day is not only economy but speed in returning equipment to the road for service.

The advocates of longitudinal shops figure on floor space per engine. In doing so they count the middle communication track as covered with engines, which is erroneous, or crowd the engines closer together on the outside tracks than economical or actually done in practice. If comparisons are made on a correct basis and attention paid to the fact that recent longitudinal shops are being built with wider track spacing and width of shop than older ones, it will be found that cross shops require less floor space per engine than longitudinal shops. Mr. R. H. Soule, in a discussion on locomotive erecting shops (American Engineer and Railroad Journal, April, 1903), reaches the conclusion that cross shops with transfer table or with overhead cranes for traversing engines require less floor space and cubic volume of building per engine than a longitudinal shop.

Longitudinal shop advocates claim that they can increase the engine standing capacity not only by standing engines on the middle communication track, but also by placing engines on trestles between the track. It is true that a few engines can be placed on the middle track and stripped, provided the outlook shows that no engines will be ready to leave the shop until the middle track will be free. But the objection to this scheme is that, under the pressure to get engines into the shop and

started, this middle track will be filled up, thus holding completed engines in the shop and out of service. The middle track is the communication track and should be kept practically open all the time and the capacity of the shop figured accordingly. In regard to placing engines between longitudinal pits, spaced 22 ft. to 25 ft. centers, which is current practice, it is just as feasible to place them between cross pits spaced 22 to 24 ft. centers, which is the modern spacing for cross pits. To clutter the floor space with extra engines and dismantled parts is certainly not economical or conducive to quick work. It sounds well to have a large number of engines in a limited space, but total shop output tells the story.

In regard to height of side walls and buildings, the crane girder runways of modern longitudinal shops are only from 6 to 12 ft. below the runway in cross shops with heavy traversing crane, and usually the increased height of erecting shop is advantageous to get better light from the upper windows above the adjacent machine shop roof. On the other hand, cross shops with heavy traversing crane are narrower than the modern longitudinal shops. But even admitting this extra height of building, it does not warrant disregarding any possible advantages that the cross shop may have, especially as the question is not entirely one of first cost of structures.

In longitudinal shops two cranes are used for transferring engines from the middle to the side track. The cranes are usually each from 50 to 70 tons capacity, so that one crane can handle a boiler, or both cranes pick up and move sideways the heaviest engine. Cross shops have one heavy crane of 100 to 120 tons capacity for use in lifting and traversing engines, with auxiliary lighter

and quick speed cranes on a lower level for general service. The longitudinal shop offers two fairly heavy crane units, which are available for light work at different points when not required for transferring engines, but they cannot pass each other in handling light work. In the cross shop there is only one very heavy crane available for general service in addition to light cranes on a lower level, better adapted for general service, as they are moved more quickly and can pass under the heavy crane. When an engine has to be transferred the longitudinal draws on two cranes, where the cross shop draws only on one, leaving one other small one free for general service. In both cases there are two crane men required. As far as service is concerned the two cranes in the cross shop will give more service than the two in the longitudinal shop. As regards first cost, two 50 to 70-ton cranes will cost as much, if not slightly more, than one 100 to 120-ton crane, so that the difference in first cost is, as a general statement, the increased cost of the light auxiliary crane in the cross shop, and the convenience of having such light cranes will offset the extra cost.

In order to obviate the necessity of keeping the middle track in a longitudinal shop open so as to serve for communication, one of the best known motive power superintendents of the country has advanced the proposition that in modern longitudinal shops, which are about 80 ft. wide and with tracks spaced 22 to 24 ft. centers, engines can be picked up by the cranes and only hoisted high enough to pass over any wheels or dismantled parts that may be in the aisle between the center track and the wing or side track, and then that such engine can be carried by the cranes lengthwise over

the aisle and between engines standing on the center or side tracks. This can be done, but it is a delicate operation to traverse the two cranes together uniformly, and, if the length of the shop is large, the time consumed so as to work safely and the risk involved is considerable, unless the cranes are provided with swinging arms which can be used to connect the two cranes temporarily rigidly together. During this operation both cranes are withdrawn from general work in the shops. This proposition cannot be considered as a visible improvement in the design of longitudinal shop. It is simply a shop-kink or expediency measure to overcome a recognized defect of the system, viz.: that for a given shop area the number of standing engines has to be reduced if the middle track is reserved, as it should be, for an open communication track.

It is further frequently claimed that the width of the erecting shop and span of crane in a longitudinal shop is less than in a cross shop. A comparison of recently built longitudinal shops and cross shops with heavy traversing crane shows the following crane spans:

Longitudinal shops.—Juniata, 67 ft., recent extension, 76 ft.; Concord, 66 ft. 4 in.; Dubois, 68 ft.; Elizabethport, 80 ft.; Fort Wayne, Ind., 82 ft.; Columbus, O., 77 ft.; Omaha, 69 ft. 9 in.; Topeka, 72 ft.; Montreal, 77 ft., and East Moline, Ill., 95 ft.

Cross shops with heavy traversing crane.—McKees Rocks, 66 ft.; Reading, 66 ft.; Collinwood, 65 ft. 6 in.; Sayre, 59 ft. 7 in.; Brooks Locomotive Works, 64 ft. 4 in.; Richmond Locomotive Works, 70 ft.; Paterson Locomotive Works, 60 ft.

It is not necessary to have the crane span over 60 ft. in a cross shop with traversing crane if one side or both

sides of the erecting shop are provided with additional bays of lower roof construction under which the wheels and sundry work around the engine can be performed.

A comparison of crane spans, therefore, shows if anything in favor of cross shops with traversing crane.

As to actual speed of the crane work in transferring engines, statements vary considerably. It is probable that there is not very much difference in the time between the two systems as far as actual transfer of engines is concerned . The principal work is preparatory to making the move and subsequently removing the hoisting frame and slings, all of which is the same whether the engine is hoisted just clear of the floor or about 15 ft. higher so as to clear engines.

The claim is frequently made that in a large shop the longitudinal layout offers a shorter building. This cannot be demonstrated on a fair basis. The figures are generally in such case compiled on the basis of filling up the middle communication track with engines, thereby blocking all movement in and out of the house and not allowing sufficient room for passageways and working around the ends of engines. Mr. R. H. Soule, in the article referred to above, figures out and states that a cross shop is shorter and "more compact" than a longitudinal shop.

With tracks 22 to 24 ft. centers in a cross shop and allowing 45 to 50 ft. per engine on the two working tracks of a longitudinal shop, the total length of the building is about the same. To make two erecting shops so as to cut the building length in two would seem more objectionable in the longitudinal plan than in the cross plan with heavy traversing cranes. The main feature is to get one machine shop in the middle. By doubling the

erecting shops in a cross shop, which is not so objectionable, the length of the cross shop will be about one-half of a longitudinal shop for the same number of engines.

The advocates of both systems claim that their particular system is the best for freedom of observation of the workmen and unobstructed view of the shop operations. In the longitudinal shop, the foreman walking down the middle aisle can see a long distance, but the workmen can also see him coming. He can only see the men on one side of the engines unless he makes three trips the length of the shop. In the cross shop the foreman in walking down the aisle at either end of the engines has about one-half the distance to travel to see all the engines, comes on the various squads of men unawares, and can see each engine complete excepting one end, and that he can take in on his return trip in the other aisle. To see all sides of all engines the foreman in the longitudinal shop has to travel twice the distance as in the cross shop before he gets back to his office.

Much emphasis is laid on the fact that in a longitudinal shop the engines are close to the machine shop. This is true of one pit, but not of the other. The transfer from the distant track to the machine shop across the pits, and especially if the middle tracks and space between tracks is filled with engines, and the floor generally cluttered with dismantled parts, is certainly more difficult than in the cross shop. In the latter the wheels when free are simply rolled back towards the machine shop side on the same pit tracks, and vice versa, are returned in a similar way. There may be advantages in a longitudinal shop where manufacturing new engines only is done, as all new parts are brought from other shops on the middle track to the engine, provided there

are no engines placed on the middle track, dropped off on the floor and then assembled. But in a repair shop, where all movements are double, from the engine and back to the engine, this double movement over pits and tracks sideways is certainly objectionable.

The only remedy is to duplicate the machine shop in two units, one on each side of the longitudinal shop, which plan was adopted at the Dubois shops of the Buffalo, Rochester & Pittsburgh, built in 1901; Concord shops of the Boston & Maine, in 1898; Aguas Calientes shops of the Mexican Central, in 1902, and Topeka shops of the Atchison in 1902. This scheme cuts off good side light from the erecting shop, and it is objectionable to have two machine shops if it can be avoided. The engines in a cross shop can be placed just as close to the machine shop as on the first pit in the longitudinal shop, while the other pit in the longitudinal shop is certainly at a serious disadvantage unless the double machine shop is adopted.

Arguments have been made for one or the other system based upon the sum of all distances traveled from the center of each shop to the center of all other shops in the group. These figures are misleading, whichever way they may tend, and are not representative of actual conditions.

In the cross shop of the Pittsburgh & Lake Erie at McKees Rocks, the building is located with reference to the yard so that a yard track enters the building without a turn-table. At the Collinwood shops of the Lake Shore, the Reading shops of the Philadelphia & Reading and the Sayre shops of the Lehigh Valley, turn-tables have to be used to take engines in or out of the shop. Turn-tables are objectionable, but they can be floored over to keep the pit from filling with snow.

A summary of some recent installations of large locomotive shops since about 1890 is given below:

1.—Longitudinal shops:

Pennsylvania, Juniata shops, Altoona, Pa., 1890. Longitudinal erecting shop with machine shop in a separate building. The choice of the longitudinal system was, no doubt, influenced by the fact that the Pennsylvania had previously used this system at the old locomotive shops at Altoona and at other places: the decision was also probably based largely on the report of the committee sent abroad to investigate shop practice when the large Horwich shops in England had just been completed. It is significant that while in 1903 the Juniata shops has been extended necessarily as a longitudinal shop, at the old locomotive shops a transfer table has been replaced by a covered traversing overhead crane for handling locomotives. As the Juniata shop is a manufacturing plant, the conditions at that point are not, however, fairly represeutive of repair shop practice.

Well known older longitudinal plants, built prior to 1890, are the large Horwich shops, England, where considerable manufacturing is done in addition to repair work, and the Norfolk and Western shops at Roanoke, Va., but the latter has only space for about 24 engines and boilers on the working tracks. The Horwich shop, while 1,520 feet long, is very narrow and low and built to suit small English engines; there are two 48-foot erecting shops with narrow 17-foot machine space between them. In the Juniata, Horwich and Roanoke shops, the machine shop is in a separate building from the erecting shop.

The Boston and Maine adopted a longitudinal erecting shop in 1898, at Concord, with double machine shops, but it has space for only 12 engines on the working tracks.

Mexican Central, Aguas Calientes, Mex., 1902. Longitudinal shop, with double machine shops, with room for only about 20 engines and boilers.

Buffalo, Rochester and Pittsburgh, Dubois, Pa., 1901. Longitudinal shop with double machine shops. Total capacity, 14 engines.

Central Railroad of New Jersey, Elizabethport, N. J., 1901. Longitudinal shop with machine shop on one side. Capacity, 20 engines on working tracks.

Union Pacific, Omaha, Neb., 1902. Longitudinal shop with single machine shop. Capacity, 18 engines.

Atchison, Topeka and Santa Fe, Topeka, Kan., 1902. Longitudinal shop with double machine shops. Capacity, 24 engines.

Canadian Pacific, Montreal, Can., 1902. Longitudinal shop with single machine shop. Capacity, 42 engines.

Chicago and Rock Island, East Moline, Ill., 1903. Longitudinal shop with double machine shops and engines placed diagonally in place of parallel to center track. Capacity, 38 repair pits.

Further, a number of longitudinal shop buildings have been erected at old shop plants, where the former layout controlled the selection or this class of shop had been used on other parts of the system, and hence, was favored.

The engine capacity of longitudinal shops is an uncertain figure, dependent on the spacing of the engines on the longitudinal tracks and also, as a rule, boiler and tank repairs are made on the same tracks, the exact distribution of space depending on the working conditions.

2.—Cross shops with heavy traversing crane:

Philadelphia and Reading, Reading, Pa., 1901. Capacity, 70 erecting pits, independent of boiler and tank repairs.

Lake Shore and Michigan Southern, Collinwood, O., 1902. Capacity, 24 erecting pits, independent of boiler and tank repairs.

Pittsburgh and Lake Erie, McKees Rocks, Pa., 1902. Capacity, 24 erecting pits, independent of boiler and tank repairs.

Lehigh Valley, Sayre, Pa., 1903. Capacity, 48 erecting pits, independent of boiler and tank repairs.

In addition, four of the leading locomotive manufacturing contract plants are using heavy overhead traversing cranes. At the Baldwin Works, Philadelphia, the cranes have been in use since 1890, and semilar cranes have been installed in 1899 at the Brooks' Works, Dunkirk, and in 1902 at the Richmond Locomotive Works, and in the Patterson Locomotive Works. Inquiries of such contract manufacturing companies indicate that they would adopt the heavy traversing cranes in designing a new plant even if they had plenty of ground space available, as a general proposition.

It is pertinent to note that in England, where for years the longitudinal shop has been the preferred type, the cross shop with heavy traversing crane for lifting

engines over each other sideways has been adopted, for instance, at the Inverurie shops of the Great North of Scotland Railway, built about 1900. Also that the German Government engineers are working on designs for a locomotive cross shop with overhead cranes for traversing engines.

The recent introduction of the double machine shop scheme at the longitudinal shops at Dubois, Concord, Aguas Calientes and Topeka, would seem to be an acknowledgment of the defects of the old longitudinal shop with one machine shop. The peculiar and ingenious layout of the Rock Island longitudinal shop at East Moline, Ill., with a 100 ft. wide central erecting shop and a machine shop on one side and a boiler shop on the other, and engines placed on pits diagonally to the centerline of the shop, would indicate another scheme to remedy the apparently well-known defects of the old style longitudinal shop. The East Moline layout might be classed as a compromise longitudinal and cross shop. Lifting, moving sideways and also slewing an engine through an angle of 68 degrees with two overhead cranes simultaneously, as required in the East Moline shop, is certainly a more delicate operation than traversing an engine with one crane in a cross shop.

The fact is clear that the longitudinal locomotive erecting shop of recent years differs radically from the designs of ten years ago. The improvements have all been directed to overcoming the objectionable elements of the old-style shop with a single machine shop, viz.: narrow house and close spacing of tracks; that one track is cut off from the machine shop; that there is little space for storage of dismantled parts excepting alongside of the engines; and that the middle track must be left open for

free ingress or egress of engines. The adoption in recent designs of the double machine shop, the wider spacing of the tracks, the wider and higher house, the longer crane spans, the proposition to traverse engines longitudinally over the aisles between the tracks, and finally the latest scheme adopted at Moline for setting the engines on individual pits diagonally to the center track, are all indicative of the tendency of advocates of the longitudinal shop to adhere to this system, owing to their firm belief in its operating advantages, but yet recognizing certain objectionable elements inherent in the old-style longitudinal shops. The success of longitudinal shops should be gauged by the modern installations and not by the cramped and defective single machine shop layout of the earlier period.

Attention should also be directed to the composite character of the Central of New Jersey, Elizabethport, layout, where a longitudinal shop connects with a transfer table and in addition is provided with two heavy cranes for lifting locomotives; in other words, a mechanical transfer equipment fully equal to a transfer table cross shop with light overhead cranes or to a cross shop with heavy traversing cranes. The same feature occurs in the full development scheme for the future, as shown on the adopted layout for the Dubois shops, where a transfer table may be used some day to connect the tracks at one end of the longitudinal shop. The erecting shop at Horwich, England, has two transfer tables running across the 1,520 ft. long erecting shop to facilitate movement of engines and materials.

A prominent example of a recently built longitudinal shop, namely, at Dubois, was adopted largely through the advice of the leading consulting motive power expert

employed by the railroad company, but there was an alternate cross track plan worked up at the time which was much favored by motive power officers of the railroad company, although the longitudinal layout was finally adopted.

It has been deemed essential to go fully into this question of longitudinal vs. cross erecting shops, not only on account of the importance to a railway company of making a proper selection in such an important matter, but also so as to review the many distorted and confused ideas on the subject.

The principal conclusions reached regarding "Longitudinal vs. Cross Erecting Shops" are as follows:

Individual preferences, local conditions and requirements, the prevailing practice on each road or custom in each section of the country, will frequently influence the layout more than the alleged advantages of one or the other system; in other words, the personal equation of the motive power superintendent or consulting shop mechanical engineer and usage will largely govern. But, assuming ample space and freedom in adopting a design, the following layouts would seem the best and correspond to the trend of recent practice:

In a small general repair plant with not over 15 erecting pits, one transfer table serving all departments offers a neat, compact and economical layout.

In larger plants, up to about 25 erecting pits, where the locomotive department occupies a separate group of buildings, the longitudinal shop has in northern climates advantages over the cross shop with transfer table layout. The longitudinal shop is generally cheaper in first cost than a cross shop with heavy overhead traversing crane for lifting engines laterally over others standing

on the floor. The longitudinal shop, especially when having only one machine shop on one side of the erecting shop, will always have objectionable elements in operation as compared with a cross shop. The latest practice, using double machine shops, one on each side of the longitudinal erecting shop, while objectionable, is an improvement over the old style with one machine shop.

For very large plants, the cross shop system with heavy high traversing crane for lifting engines laterally over other engines standing on the floor is to be preferred. If the cross tracks in the building run at right angles to the general yard-track layout, then a turn-table has to be used at the entrance to the house. In northern climates the turn-table pit should be covered. If the cross tracks in the building run parallel to the yard tracks, then no turn-table is needed and the additional advantage is offered that several pits in the building can have track doors with track approach for comparatively light repairs to engines not requiring complete dismantling and unwheeling and hence such engines can be taken in and out of the house cheaply and quickly.

4.—FLOOR SPACE AND RELATIVE PROPORTIONS OF A LOCOMOTIVE REPAIR SHOP.

There is no general recognized rule or even comparative data available as to the floor space required for the several sub-departments of a locomotive shop.

The only apparent effort made heretofore to establish a general rule for the proportioning of space in locomotive shops is contained in an article by Mr. T. B. Brown, Master Mechanic, Penn. R. R., Juniata Shops, Altoona, on the "Construction of a Modern Locomotive," (Am. Engineer & R. R. Journal, Jan., 1899). Mr. Brown's

rule is presented in connection with locomotive manufacturing and not repair work, and gives no relation to number of engines to be turned out. Mr. Brown states:—

"We know of no fixed rule which can be applied to determine the amount of floor space required for a given amount of equipment. In the case of the machine shop, it will be found that for each machine the floor space required for operator, proper handling of work, etc., at that particular machine, will be very closely equal to twice the area occupied by the machine itself, the dimensions for determining the area occupied by the machine being equal to the product of its two extreme dimensions, and that the amount of floor space required in aisle room and general passageway will be approximately equal to 25 per cent. more than the space occupied by the machine. These figures do not allow for extensions or additional machines, but are intended only to include the original installation, placed as closely together as will be consistent with safety to operator and handling of material.

"In the case of the boiler shop these figures will not hold good to the same extent, owing to the fact that the material handled at machines is frequently from three to four times the area of the space occupied by the machine itself, and it is also true that in this shop fully 75 per cent. of the floor space must be left free for the general handling of material and erecting.

"In blacksmith shops the conditions are in very many respects similar to those in the boiler shops, excepting in the matter of waste floor space. There being no erecting in this shop, the greatest amount of space is required around the tools where the work is being done, and we would suggest an allowance of floor space for general handling of material equal to 50 per cent. in excess of the space occupied by the tools and that required for handling the parts in process of manufacture at these tools."

It is usually considered that the local conditions and special requirements at each shop preclude the establishing of any rule or limits. This is true to a very large extent and yet considerable information of value can be obtained from actual practice, as shown by various shop

layouts. The main advantage from such information is to obtain the general range and the apparently controlling limits of floor space necessary to take care of a given number of engines and further to establish the range and limits for the proportional sizes of the various sub-departments, assuming the erecting pit as the unit and the erecting shop as the leading department that has to be served by all the other departments.

The following tables have been prepared from the best information available. They cannot be considered strictly accurate, as the figures are compiled mainly from the original plans and published descriptions. The actual division of the work and sub-departments has no doubt in many cases been changed from the original plans. Where several sub-departments are grouped in one building without solid partitions between them, as when erecting and boiler work are done on the same set of tracks, the actual space occupied by each will fluctuate with the daily demands. In many cases a building marked on the plans as a boiler shop is used for tank shop, flue shop, heavy forging shop, casting shop, etc., where in other layouts these branches are provided for in separate buildings or placed in the blacksmith shop. In such cases the relative sub-division of the floor space cannot properly serve for comparison, but the aggregate space given for a combination of such departments is valuable.

In using the data presented full value must be given to the fact that in many cases local conditions and individual opinions of designers may have controlled the plan, as also the fact that the facilities frequently cover work for other departments than locomotive repairs. Many of the layouts, especially the older ones, were not

planned for the repairs of the heavy and large power in use to-day and the class of service and engines naturally influence the facilities required on different roads. In addition, the number of engines concentrating at a given shop is uncertain and variable. There is very little information available as to the assignment of existing shop pits for heavy and comparatively light work, and as to the amount of comparatively heavy work done at round houses and small emergency shops on the line.

The shops covered by the tables are grouped as follows:

Group 1.—Cross shop with transfer table at general repair shops, where all departments are served by one transfer table: Oelwein, Ia., Chicago Great Western; Hannibal, Mo., Chicago, Burlington and Quincy; Fond du Lac, Wis., Wisconsin Central; Denver, Colo., Colorado and Southern; Pocatello, Idaho, Oregon Short Line.

Group II. -Cross shop with transfer table at plants with separate locomotive department: West Albany, N. Y., New York Central; St. Paul, Minn., Chicago, St. Paul, Minneapolis and Omaha; Chicago, Ill., Chicago and North Western (Kinzie street shops); Jackson, Mich., Michigan Central; Chicago, Ill., Illinois Central (Burnside shops); Depew, N. Y., New York Central; Knoxville, Tenn., East Tennessee, Virginia and Georgia: Baring Cross, Ark., St. Louis, Iron Mountain and Southern; Oak Grove, Pa., New York Central; St. Paul, Minn., Great Northern (Dale street shops).

Group III. Cross shop with heavy overhead crane for traversing engines. Reading, Pa., Philadelphia and Reading; McKees Rocks, Pa., Pittsburgh and Lake Erie; Collinwood, O., Lake Shore and Michigan Southern; Sayre, Pa., Lehigh Valley.

Group IV. Longitudinal shops: Altoona, Pa., Pennsylvania (Juniata shops); Concord, N. H., Boston and Maine; Du Bois, Pa., Buffalo, Rochester and Pittsburgh; Elizabeth, N. J., Central of New Jersey; Omaha, Neb., Union Pacific; Topeka, Kan., Atchison, Topeka and Santa Fe; Montreal, Canada, Canadian Pacific; East Moline, Ill., Chicago and Rock Island.

TABLE "A"—LOCOMOTIVE REPAIR SHOPS—SQUARE FEET OF FLOOR SPACE PER ERECTING PIT.

	Year built.	Erecting pits. No.	Erecting shop.	Machine shop.	Total erecting and machine shop.	Boiler shop.	Total of three main depts.	Blacksmith shop.	Total of four main depts.	Additional bldgs.	Total all bldgs.
Group I—											
Oelwein, Ia.	1899	15	1,626	1,760	3,386	626	4,012	*508	4,520	1,335	5,855
Hannibal, Mo.	1901	10	1,518	1,610	3,128	673	3,801	*867	4,668	1,991	6,659
Fond du Lac, Wis.	1901	15	1,419	1,419	2,838	757	3,595	*757	4,352	1,775	6,127
Denver, Col.	1901	9	1,599	1,482	3,081	799	3,880	*798	4,678	842	5,522
Pocatello, Idaho	1902	10	1,688	1,687	3,375	1,950	5,325	*1,275	6,600	1,305	7,905
Group II.—											
West Albany, N. Y.	Old	42	1,890	1,983	3,873	117	3,990	615	4,605	....	....
St. Paul (Omaha R. R.)	Old	15	1,320	1,426	2,746	2,144	4,890	720	5,610	1,087	6,697
Chicago (C. & N. W.)	Old	25	1,510	1,904	3,414	1,380	4,794	1,280	6,074	3,646	9,720
Jackson, Mich.	Old	30	1,639	1,309	2,948	380	3,328	350	3,678	2,122	5,800
Chicago (Ill. Central)	1892	25	1,760	1,760	3,520	800	4,320	*2,074	6,394	1,402	7,796
Depew, N. Y.	1892	48	1,517	596	2,113	637	2,750	421	3,171	1,005	4,176
Knoxville, Tenn.	1893	16	1,204	902	2,106	756	2,862	*1,250	4,112	859	4,971
Baring Cross, Ark.	1901	15	1,560	1,365	2,925	1,800	4,725	*1,333	6,058	1,884	7,942
Oak Grove, Pa.	1902	25	2,288	1,294	3,582	3,223	6,805	644	7,449	1,228	8,677
St. Paul (Great Northern)	1902	25	1,800	1,800	3,600	2,446	6,046	1,520	7,566	3,314	10,880
Group III.—											
Reading, Pa.	1901	70	1,480	634	2,114	686	2,800	525	3,325	929	4,254
McKees Rocks, Pa.	1902	24	1,598	2,340	3,938	1,145	5,083	*650	5,733	733	6,466
Collinwood, O.	1902	24	1,535	2,208	3,743	1,734	5,477	*1,400	6,877	1,614	8,491
Sayre, Pa.	1903	48	1,647	2,039	3,686	1,484	5,170	*1,092	6,262	2,652	8,914
Group IV.—											
Altoona, Pa. (Juniata)	1890	14	1,770	2,764	4,534	2,206	6,740	1,748	8,488	2,374	10,862
Concord, N. H.	1897	12	1,779	1,525	3,304	612	3,916	500	4,416	1,339	5,755
Dubois, Pa.	1901	14	1,770	1,618	3,388	1,627	5,015	811	5,826	1,836	7,662
Elizabethport, N. J.	1901	20	2,000	1,750	3,750	1,500	5,250	*1,200	6,450	1,551	8,001
Omaha, Neb.	1902	18	1,667	1,667	3,334	2,033	5,367	*1,220	6,587	2,872	9,459
Topeka, Kan.	1902	24	1,700	1,817	3,517	1,912	5,429	*1,667	7,096	1,042	8,138
Montreal, Canada	1902	42	1,739	1,739	3,478	1,386	4,864	*1,879	6,743	1,871	8,614
East Moline, Ill.	1903	44	1,910	1,675	3,585	1,733	5,315	844	6,162	2,046	8,208

*Blacksmith shop includes work for car department.

TABLE "B"—LOCOMOTIVE REPAIR SHOPS—RELATIVE SIZE OF BUILDINGS IN PERCENTAGE OF ERECTING SHOP.

	Year built.	Erecting pits. No.	Erecting shop.	Machine shop.	Total erecting and machine shop.	Boiler shop.	Blacksmith shop.	Total of four main depts.	Additional bldgs.	Total all bldgs.
Group I.—										
Oelwein, Ia.	1899	15	100.0	108.2	208.2	38.5	*31.2	277.9	82.1	360.0
Hannibal, Mo.	1901	10	100.0	106.1	206.1	44.3	*57.1	307.5	131.2	438.7
Fond du Lac, Wis.	1901	15	100.0	100.0	200.0	53.3	*53.3	306.6	125.2	431.8
Denver, Col.	1901	9	100.0	92.7	192.7	50.0	*50.0	292.7	52.7	345.4
Pocatello, Idaho	1902	10	100.0	100.0	200.0	115.5	*75.6	391.1	77.4	468.5
Group II.—										
West Albany, N.Y.	Old	42	100.0	52.0	152.0	59.1	32.5	243.6	....	....
St. Paul (Omaha R. R.)	Old	15	100.0	108.0	208.0	162.4	54.6	425.0	82.3	507.3
Chicago (C. & N. W.)	Old	25	100.0	126.1	226.1	91.4	84.8	402.3	241.5	643.8
Jackson, Mich.	Old	30	100.0	79.8	179.8	23.2	21.4	224.4	129.5	353.9
Chicago (Ill. Central)	1892	25	100.0	100.0	200.0	45.4	*118.1	363.5	79.7	443.2
Depew, N. Y.	1892	48	100.0	39.3	139.3	42.0	27.8	209.1	66.2	275.3
Knoxville, Tenn.	1893	16	100.0	75.0	175.0	62.8	*103.8	341.6	71.4	413.0
Baring Cross, Ark.	1901	15	100.0	87.5	187.5	115.4	*85.2	388.1	120.7	508.8
Oak Grove, Pa.	1902	25	100.0	56.5	156.5	140.9	28.1	325.5	53.7	379.2
St. Paul (Great Northern)	1902	25	100.0	100.0	200.0	136.0	84.3	420.3	184.1	604.4
Group III.—										
Reading, Pa.	1901	70	100.0	42.9	142.9	46.3	35.5	224.7	62.7	287.4
McKees Rocks, Pa.	1902	24	100.0	146.5	246.5	71.7	*40.7	358.9	45.9	404.8
Collinwood, O.	1902	24	100.0	143.8	243.8	112.9	*91.2	447.9	105.2	553.1
Sayre, Pa.	1903	48	100.0	123.8	223.8	90.1	*66.3	380.2	161.0	541.2
Group IV.—										
Altoona, Pa. (Juniata)	1890	14	100.0	156.2	256.2	124.6	98.8	479.6	134.1	613.7
Concord, N. H.	1897	12	100.0	85.7	185.7	34.4	28.1	248.2	75.3	323.5
Dubois, Pa.	1901	14	100.0	91.4	191.4	91.9	45.9	329.2	103.7	432.9
Elizabethport, N. J.	1901	20	100.0	87.5	187.5	75.0	*60.0	322.5	77.5	400.0
Omaha, Neb.	1902	18	100.0	100.0	200.0	122.0	*73.2	395.2	172.3	567.5
Topeka, Kan.	1902	24	100.0	106.9	206.9	112.5	*98.0	417.4	61.3	478.7
Montreal, Canada	1902	42	100.0	100.0	200.0	79.7	*108.0	387.7	107.6	495.3
East Moline, Ill.	1903	14	100.0	87.6	187.6	91.0	44.3	322.9	107.1	430.0

*Blacksmith shop includes work for car department.

TABLE "C"—LOCOMOTIVE REPAIR SHOPS—RELATIVE SIZE OF THE MAIN DEPARTMENTS.

	Year built.	Erecting pits. No.	Percentage of four departments. Erecting shop.	Machine shop.	Boiler shop.	Blacksmith shop.	Erecting and machine shops.	Boiler and blacksmith shops.	Per cent. of three departments. Erecting shop.	Machine shop.	Erecting and machine shops.	Boiler shop.
Group I.—												
Oelwein, Ia.	1899	15	36.0	38.9	13.8	*11.3	74.9	25.1	40.5	43.9	84.4	15.6
Hannibal, Mo.	1901	10	32.5	34.5	14.4	*18.6	67.0	33.0	39.9	42.4	82.3	17.7
Fond du Lac, Wis.	1901	15	32.6	32.6	17.4	*17.4	65.2	34.8	39.5	39.5	79.0	21.0
Denver, Col.	1901	9	34.1	31.7	17.1	*17.1	65.8	34.2	41.2	38.2	79.4	20.6
Pocatello, Idaho	1902	10	25.6	25.6	29.5	*19.3	51.2	48.8	31.7	31.7	63.4	36.6
Group II.—												
West Albany, N. Y.	Old	42	41.1	21.3	24.3	13.3	62.4	37.6	47.3	24.7	72.0	28.0
St. Paul (Omaha R.R.)	Old	15	23.6	25.4	38.2	12.8	49.0	51.0	27.0	29.2	56.2	43.8
Chicago (C. & N. W.)	Old	25	24.9	31.3	22.7	21.1	56.2	43.8	31.5	39.7	71.2	28.8
Jackson, Mich.	Old	30	44.6	35.6	10.3	9.5	80.2	19.8	49.3	39.3	88.6	11.4
Chicago (Ill. Central)	1892	25	27.5	27.5	12.5	*32.5	55.0	45.0	40.8	40.7	81.5	18.5
Depew, N. Y.	1892	48	47.8	18.8	20.1	13.3	66.6	33.4	55.2	21.7	76.9	23.1
Knoxville, Tenn.	1893	16	29.3	21.9	18.4	*30.4	51.2	48.8	42.1	31.5	73.6	26.4
Baring Cross, Ark.	1901	15	25.8	22.5	29.7	*22.0	48.3	51.7	33.0	28.9	61.9	38.1
Oak Grove, Pa.	1902	25	30.7	17.4	43.3	8.6	48.1	51.9	33.6	19.0	52.6	47.4
St. Paul (Gt. North)	1902	25	23.8	23.8	32.8	20.1	47.6	52.4	29.8	29.8	59.6	40.4
Group III.												
Reading, Pa.	1901	70	44.5	19.1	20.6	15.8	63.6	36.4	52.9	22.6	75.5	24.5
McKees Rocks, Pa.	1902	24	27.9	40.8	20.0	*11.3	68.7	31.3	31.5	46.0	77.5	22.5
Collinwood, O.	1902	24	22.3	32.1	25.2	*20.4	54.4	45.6	28.0	40.3	68.3	31.7
Sayre, Pa.	1903	48	26.3	32.6	23.7	*17.4	58.9	41.1	31.9	39.4	71.3	28.7
Group IV.—												
Altoona, Pa. (Juniata)	1890	14	20.8	32.6	26.0	20.6	53.4	46.6	26.3	41.0	67.3	32.7
Concord, N. H.	1897	12	40.3	34.5	13.9	11.3	74.8	25.2	45.4	38.9	84.3	15.7
Dubois, Pa.	1901	14	30.4	27.7	27.9	14.0	58.1	41.9	35.3	32.3	67.6	32.4
Elizabethport, N. J.	1901	20	31.0	27.1	23.3	*18.6	58.1	41.9	38.1	33.3	71.4	28.6
Omaha, Neb.	1902	18	25.3	25.3	30.8	*18.6	50.6	49.4	31.1	31.1	62.2	37.8
Topeka, Kan.	1902	24	24.0	25.6	26.9	*23.5	49.6	50.4	31.3	33.5	64.8	35.2
Montreal, Canada	1902	42	25.8	25.8	20.6	*27.8	51.6	48.4	35.7	35.7	71.4	28.6
East Moline, Ill.	1903	44	31.0	27.1	28.2	13.7	58.1	41.9	35.9	31.4	67.8	32.7

*Blacksmith shop includes work for car department.

From an examination of the tables and with due regard to the special conditions existing at the various plants, the following average figures can be given as a general rule for proportioning *large* locomotive repair shops:

1.—Floor space per erecting pit in sq. ft.:

Erecting shop	1,750	
Machine shop	2,450	
		4,200
Boiler shop		1,575
Blacksmith shop		1,225
Total of four main departments		7,000
Additional buildings		1,750
Total, all buildings		8,750

2.—Relative size of four main departments in percentage of erecting shop:

Erecting shop	100	
Machine shop	140	240
Boiler shop		90
Blacksmith shop		70
Total of four main departments		400
Additional buildings		100
Total, all buildings		500

3.—Relative size of four main departments in percentage of total of the four departments:

Erecting shop	25	
Machine shop	35	
		60
Boiler shop	22.5	
Blacksmith shop	17.5	
		40
Total of four main departments		100

4.—Relative size of the three main departments in percentage of total of the three departments:

Erecting shop	30.3	
Machine shop	42.4	
		72.7
Boiler shop		27.3
Total of three departments		100.0

The above figures for boiler shop include tank shop. Where the blacksmithing is absolutely only for the locomotive department, the above percentage for blacksmith shop can be reduced.

The above recommended averages will give larger floor areas than are found in small division shops, where all departments for locomotive and car repairs are grouped around one transfer table.

The tables indicate that in nearly all modern plants the machine shop is made at least equal to the erecting shop, and generally larger, emphasizing the necessity of having ample machine room to back up the erecting work, so that the erecting pits do not become merely engine storage pits.

5.—NUMBER OF ERECTING PITS.

The proper size of the locomotive shop layout depends on the erection shop, i. e., on the number of erecting pits, and the latter on the total number of engines that the shop in question has to keep in repair and the number of new engines to be built yearly, where this is done.

Reliable data on this subject is hard to obtain, especially as to the number of engines requiring heavy repairs and boiler work and those calling only for comparatively light repairs. On most railroads a large amount of repair work, even of a heavy character, is done at various small division or emergency shops on the system and hence the statements what a shop is doing or the published account of the number of engines it is expected to take care of are very misleading, particularly if manufacturing is done in addition to repairing.

The information at hand is as follows:

1. Buffalo, Rochester and Pittsburgh Shops, Du Bois, Pa., 1901. Total engines, 183. Number to be repaired at Du Bois in 1901 stated to be 147, and an allowance of 15 engines increase per year for five years was made. The total number of engines to be provided was, therefore, 200, or, if each engine is to be put through the shop once a year for heavy repairs, 17 engines per month. The designers assumed 20 days for each engine in the shop, and that each pit would, therefore, turn out 1½ engines per month, and 12 pits would provide for 18 engines per month. Assuming one-third as many boilers and tanks in the shop as engines, the above equipment of 200 engines would require a shop capacity for 12 engines, six boilers and six tanks at one time. Shops were built for 14 engines on working tracks.

Hence the ratio of engine pits to equipment, at the time of construction was 9.5 per cent., and allowing for five years' increase, 7 per cent.

2. Pittsburgh and Lake Erie, McKees Rocks, Pa., 1902. New plant designed with 24 erecting pits and 18 boiler tracks. Equipment, in 1902, 142 locomotives, or engine pit ratio, 17 per cent. Technical journals state that the total equipment will be 180 engines in 1903, making the pit ratio 11.3 per cent. This shop cannot be extended, and hence the capacity was evidently made looking forward to the future increase of equipment.

3. Great Northern, St. Paul Shops. New locomotive shop, 1902, at St. Paul, 25 erecting pits. Published statement that about 300 engines dependent on this shop, or pit ratio 8.3 per cent. It is expected that considerable heavy repairs from other shops will be sent here, hence, ratio probably between 7 and 8 per cent.

4. Lake Shore and Michigan Southern, Collinwood, O., 1902, 24 erecting pits. Total equipment, 582 engines. Published statement, taking care of 350 engines in 1902, or engine pit ratio, 7 per cent. It is claimed that the facilities will eventually allow 450 engines per year to be taken care of, or pit ratio 5.3 per cent.

5. Chicago and Northwestern, Kinzie street, Chicago. Old shops, 25 erecting pits, 14 boiler tracks. Total equipment, 1,060 engines; engine pit ratio, 2.4 per cent. Published statement says that there are about 1,070 engines to take care of, and the boiler repairs are concentrated for 1,185 engines. This company in 1902 was looking into the question of obtaining additional pit capacity.

6. Chicago Great Western, Oelwein, Iowa, 1898, 15 erecting pits, four boiler tracks. Total equipment, 209, practically all concentrated at Oelwein, which is the junction of three divisions. Engine pit ratio, 7.1 per cent.

7. Colorado Southern, Denver, Col., 1900, 9 erecting pits. Total equipment, 173 engines. Published statement states that this shop is expected to take care of 144 engines, or engine pit ratio, 6.3 per cent.

8. Ohio and Mississippi, Washington, Ind. Old shops, 8 erecting pits. Published statement, shop to take care of 100 engines, or engine pit ratio, 8 per cent.

9. Oregon Short Line, Pocatello, Idaho, 1902, 10 erecting pits. Total equipment, 177 engines. Assumed all concentrated at Pocatello; engine pit ratio, 5.7 per cent.

10. Southern, Sheffield, Ala., 1902, five erecting pits. Published statement, shop to take care of 80 engines. Engine pit ratio, 6.3 per cent.

11. Minneapolis and St. Louis, Cedar Lake, Minneapolis. Old shops, extended 1902. Engine pits, 10. Total equipment, 76 engines. Published statement, shop to take care of 80 engines. Engine pit ratio, 13.2 per cent.

12. Louisville, New Albany and Chicago (now Chicago, Indianapolis and Louisville), Lafayette, Ind., 1895. Engine pits, 9. Total equipment, 93 engines. Engine pit ratio, 9.7 per cent.

13. Wisconsin Central, Fond du Lac, Wis., 1901. Engine pits, 15. Total equipment, 157 engines. Published statement, shops to take care of 150 engines. Engine pit ratio, 10 per cent.

14. Missouri Pacific, Baring Cross, Ark., 1901. Engine pits, 24, of which 15 are assigned to engines and 9 to boilers. Published statement says that about 90 per cent. of 210 engines in that territory, or 189 engines, are repaired at Baring Cross. Engine pit ratio, 8 per cent.

15. New York Central. Total equipment as per equipment list, 1,368 engines. Total of 122 engine pits on system, or engine pit ratio, 8.9 per cent. Published statement, 1,461 engines on system, or pit ratio, 8.3 per cent. Over 250 round house pits have been built within recent years, and the system of small machine shops at round houses for taking care of comparatively heavy repairs is very fully developed, thereby relieving the repair shops.

16. Philadelphia and Reading. Total equipment, 951 engines. Main locomotive shops at Reading, Pa., built in 1901; 70 erecting pits. Expected eventually to take care of the heavy repairs of practically the entire equipment of 951 engines in 1902, making the pit ratio 7.4 per cent. As some engines will be taken care of elsewhere, the true pit ratio is probably about 8 per cent. Published statement says that eventually this shop is expected to take care of 1,000 engines, or pit ratio, 7 per cent.

17. Central of New Jersey. Total equipment, 476 engines. Main locomotive shop, Elizabethport, N. J. Built 1901. Longitudinal shop, 700 feet long, of which 500 feet is expected to be used for engines and 200 feet for boilers and tanks. There are also locomotive shops at Ashley, Pa., which have six pits in the main shop and six pits assigned for repair work in the round house, making 12 pits. The two

shops give a total of 37 pits for 476 engines, or engine pit ratio, 7.8 per cent.

18. Delaware, Lackawanna and Western. Total equipment, 654 engines, of which a large number new engines bought within recent years, hence, for the present, repairs not as heavy as they will be in several years. The present engine pit ratio is 7.5 per cent. In addition, considerable comparatively heavy work is done at a number of round houses where there are drop pits. This company has certain improvements under way which will give an engine pit ratio of 8.7 per cent. on the basis of present engine equipment. Allowing for regular increase of engines, the ratio will probably not drop below 8 per cent. for at least five years after the improvements are completed.

19. The annual statement of one of the prominent Eastern trunk lines states that, in comparison with engines concentrating and taken care of at the various shops, the pit ratios at the several shops were 8.4 per cent., 10.4 per cent., and 10.9 per cent. The actual average number of engines assigned to each territory and shopped at one time proved to have been at the same shops respectively 8 per cent., 10.4 per cent. and 9.1 per cent.

20. Chicago and Rock Island, East Moline, Ill., 1903. Published statement, locomotive department with 38 erecting pits, designed to repair 60 engines per month, or an average of about 20 days per engine.

21. Atchison, Topeka and Santa Fe, Topeka, Kan., 1902. Capacity, 24 engines. Published statement, the new shop is expected to build 25 or 30 new engines yearly, and that the monthly output will be about 40 engines, built, rebuilt and repaired. The Atchison system has about 1,100 engines, and there are additional shops at Albuquerque, N. M., Clebourne, Tex., and San Bernardino, Cal.

22. Chicago, Milwaukee and St. Paul, West Milwaukee, Wis. Old shops, extended in 1902, from 18 erecting pits to 25 pits. Published statement that over 400 engines dependent on this shop for repairs, also considerable manufacturing done.

23. Chicago, St. Paul, Minneapolis and Omaha, Sioux City, Iowa. New locomotive shops, 1903, with 8 erecting pits. Published statement that 140 engines depend on this shop. Pit ratio, 5.7 per cent.

The pit ratio, while valuable up to a certain point, is not absolutely conclusive as to the actual work that

can be done, as the fact of having erecting pits for storage purposes, so to say, is not indicative of shop output, which depends on the machine equipment, boiler work facilities and crane service, and on the class of engines and the road service.

Practice indicates that the number of erecting pits is from 6 to 10 per cent. of the number of engines taken care of, and that an engine pit ratio of about 8 per cent. is the average practice. The desirable theoretical ratio is frequently set at 10 per cent., but few roads have succeeded in holding this ratio. In most cases a large number of comparatively heavy repairs are made at roundhouses, especially where these are equipped with drop pits and particularly where a small machine shop annex is added to the roundhouse, so that many roads get along with less shop pits and shop equipment than desirable and economical.

In order to ascertain the number of engines that can be taken care of on a given number of pits, it is necessary to make some assumption from practice as to the length of time required to overhaul an engine and also to make light repairs. With a pit ratio of 8.33 per cent., or $^1/_{12}$ of the equipment in the shops at the same time, and if each engine required one month a year for light and heavy repairs, the entire equipment could be put through the shop in one year. Motive power men usually claim that every engine should be shopped once a year for light repairs, from three to six days, and once every 12 to 18 months for general overhauling, the time required for the latter work being placed at from three to five weeks. On the other hand, instances are frequently quoted where, under certain classes of service and conditions, engines are not shopped for heavy repairs, i.e., gen-

eral overhauling, but once every three or four years. It is also claimed that in modern plants an engine can be overhauled and receive general repairs in less than three weeks, dependent upon the shop equipment and the size of the engine. This question, therefore, is largely one of assumptions, based upon the results accomplished in similar shops and the special conditions affecting the wear and tear of engines on each road according to the strain put upon the motive power due to the heavy business, sharp curves, long grades, etc.

The proper method would seem to be to settle the number of pit days required per year for building new engines and for all light repairs on the regular shop erecting pits, making allowance for work done at small division shops or roundhouses. Deduct this figure from the total available regular shop erecting pit yearly working days, and the balance will represent the shop pit working days per year available for heavy work. Assume the average number of pit days required to overhaul one engine, and the number of engines that can be cared for is easily established. The ratio of the number of engines that can be taken care of per year in relation to the full equipment will allow the average time to be settled that an engine has to remain out of the shops for a given equipment and a certain number of shop erecting pits.

As stated above, it is usually assumed where the service is heavy that every engine is shopped once a year for light repairs, and once a year for heavy repairs, but in practice few roads are able to live up to this rule. On many roads the engines are expected to stay out of the shop a year and a half or longer before requiring general repairs. Comparisons of the time assumptions on differ-

ent railroads are not reliable owing to the varying conditions, as it is obvious that a heavy engine making a large mileage, with heavy tonnage, fast speed, long grades, bad water, etc., will run down and wear out sooner than a light engine hauling light trains under favorable conditions. The time assumption as to the average frequency of shopping engines must be established for each individual railroad or district of a railroad system.

CHAPTER IV.

PASSENGER CAR REPAIR SHOPS.

1.—EXAMPLES OF PASSENGER CAR REPAIR SHOP LAYOUTS.

The following examples of well-known or recently built passenger car repair shops, grouped upon the basis of the classification adopted above, will serve to illustrate recent practice.

A:—CROSS TRACK LAYOUT WITH TRANSFER TABLE.

1. At all general repair shops where one transfer table serves all departments, and hence, transfer table a necessity.

2. At the following general repair shops with all departments grouped along separate transfer tables:

Kinzie Street, Chicago. Old shop layout.

Southern California, San Bernardino, Cal. Old shops, extended 1902.

3. At the following general repair shops with longitudinal freight car shop, all other departments separate transfer tables:

Nashville, Tenn., 1890.

Tacoma, Wash., 1891.

Burnside, Chicago, 1892.

Knoxville, Tenn., 1893.

Bloomington, Ill. Old shops.

West Milwaukee, Wis. Old shops.

Kinzie Street, Chicago. Old shops, extended 1901.

Baring Cross, Ark., 1901.

Sheffield, Ala., 1902.

Cedar Lake, Minn. Old shops.

4. At the following general repair shops with longitudinal locomotive erecting shop and all other departments with transfer tables:

Boston and Maine, Concord, N. H., 1897.

Union Pacific Ry., Omaha, Neb. Old shops, extended 1902.

5. At the following general repair shops with longitudinal locomotive erecting shop, longitudinal freight car shop and transfer table passenger car shop:

Central of New Jersey, Elizabethport, N. J., 1901.

Atchison, Topeka and Santa Fe, Topeka, Kan. Old shops, extended 1902.

Canadian Pacific, Montreal, Can., 1902.

6. At the following general repair shops with cross locomotive erecting shop and traversing crane for lifting engines over each other, all other departments with transfer tables:

Lake Shore and Michigan Southern, Collinwood, O., 1902.

7. At the following general repair shops with cross locomotive erecting shop and traversing crane for lifting engines over each other, longitudinal freight car shop, and passenger car shop with transfer table:

Lehigh Valley, Sayre, Pa. Old shops, extended 1903.

8. At the following main car shops with longitudinal freight car shop and transfer table passenger car shop:

New York, New Haven and Hartford, Main Car Shops, Readville, Mass., 1901.

9. At main car shops with one transfer table for passenger and freight car departments:

Missouri, Kansas and Texas, Sedalia, Mo., 1898.

10. At most of the plants of passenger car manufacturing companies throughout the country.

B:—LONGITUDINAL TRACK LAYOUT.

Norfolk and Western, Roanoke, Va. Old shops, all longitudinal layout.

Pennsylvania, Altoona, Pa. Longitudinal car shops for passenger and freight cars. Old shops.

Mexican Central, Aguas Calientes, Mex. General repair shops, all longitudinal layout, 1902.

Pittsburgh and Lake Erie, McKees Rocks, Pa. General repair shops, with small longitudinal passenger car shop, 1902.

2.—LAYOUT OF PASSENGER CAR REPAIR SHOPS.

From a review of examples of passenger car repair shops there is only one possible decision to reach, and that is that in almost all instances, both in old and modern layouts, a transfer table is used.

A passenger car repair shop has the following main

departments, viz.: Erecting or main shop, paint shop, paint storehouse, cabinet shop, upholstering shop, tin-shop, carpenter shop, planing mill, storehouse, shed for finished or hardwood lumber, lumber yards, etc. In some cases there is a special passenger car truck shop. Such machine and blacksmith work as has to be done is usually attended to in the shops provided for such work in connection with the entire shop plant, as there are no cases known where a railroad passenger car repair shop is a separate plant.

There is no special rule in regard to the relative size of the various sub-departments and total floor space required in relation to the total passenger equipment of a road. Local conditions and requirements make this practically impossible to establish. In any new layout the conditions and proportions of existing shops should be studied and conclusions drawn therefrom.

CHAPTER V.

FREIGHT CAR REPAIR SHOPS.

1.—EXAMPLES OF FREIGHT CAR REPAIR SHOP LAYOUTS.

The following examples of well-known or recently built freight car repair plants, grouped upon the basis of the classification adopted above, will be of interest to indicate the best modern practice.

A:—CROSS TRACKS SERVED BY TRANSFER TABLE.

1. At all general repair shops where one transfer table serves all departments, and hence, transfer table a necessity.

2. At the following general repair shops where separate transfer tables are used for all departments:

Chicago and Northwestern, Kinzie Street, Chicago. Old shop layout.

Southern California, San Bernardino, Cal. Old shops, extended 1902.

3. At the following general repair shops with longitudinal locomotive erecting shop, otherwise all departments with transfer tables:

Boston and Maine, Concord, N. H., 1897.

Union Pacific Ry., Omaha, Neb. Old shops, extended 1902.

4. At the following general repair shops with cross locomotive erecting shop and traversing crane for lifting engines over each other, otherwise all departments with transfer tables:

Lake Shore and Michigan Southern, Collinwood, O., 1902.

B:—CROSS TRACKS WITH YARD APPROACH.

Lehigh Valley, Sayre, Pa. Old shop layout.

New York Central, West Albany, N. Y. Old shops.

C:—LONGITUDINAL TRACK LAYOUT WITH YARD APPROACH AT ONE END OF MAIN BUILDING AND TRANSFER TABLE AT OTHER END.

Nashville, Tenn., 1890.

Merchants' Despatch Company, Car Repair Shops on line of New York Central, at Despatch, N. Y., 1897.

Missouri, Kansas and Texas, Sedalia, Mo. Main car shops, 1898.

At a number of freight car construction plants of car manufacturing companies.

D:—LONGITUDINAL LAYOUT WITH TRACK APPROACH.

a.—With track approach at one end of main building:

Delaware, Lackawanna and Western, Scranton, Pa. Main freight and coal car repair shops, 1902.

Pittsburgh and Lake Erie, McKees Rocks, Pa., 1903.

Chicago and Northwestern, Kinzie Street, Chicago. Old shops, extended. New freight car repair shop added in 1901.

Chicago, Milwaukee and St. Paul, West Milwaukee, Wis. Old shops, extended 1902.

Atchison, Topeka and Santa Fe, Topeka, Kan. Old shops, extended 1902.

Canadian Pacific, Montreal, Can., 1902.

Lehigh Valley, Sayre, Pa. Old shops, extended 1903.

b.—With track approach at both ends of main building:

1. At separate freight car shop plants:

Philadelphia and Reading, Reading, 1899.

2. At main car shops with passenger car shop served by transfer table and longitudinal freight car shop:

New York, New Haven and Hartford, Readville, Mass., 1901.

3. At main car shops with longitudinal layout for passenger and for freight cars:

Pennsylvania, Altoona, Pa. Old shops.

4. At general repair shops with all longitudinal layout:

Norfolk and Western, Roanoke, Va. Old shops. (Round house also used for car repairs.)

Mexican Central, Aguas Calientes, Mex., 1902.

5. At general repair shops with various systems for locomotive erecting shop and passenger car shop, but with longitudinal freight car shop:

Nashville, Tenn., 1890.

Tacoma, Wash., 1891.

Burnside, Chicago, 1892.

Knoxville Tenn., 1893.

Wabash, Ind., 1896.

Central of New Jersey, Elizabethport, N. J., 1901.

Baring Cross, Kan., 1901.

New York Central, Oak Grove, Pa., 1902.

Sheffield, Ala., 1902.

Cedar Lake, Minneapolis. Old shops, extended 1902.

6. At most of the large freight car construction plants of car manufacturing companies.

2.—LAYOUT OF FREIGHT CAR REPAIR SHOPS.

From examples of existing freight car repair shops the prevailing practice for heavy repair work is to have a longitudinal building, i.e., run tracks through a building. The tracks are connected to yard leaders and thus form a car repair yard at each end of the building. In some cases, where the tracks are long, or one end of the property does not afford room for a yard approach to the house, a large number of designs introduce an auxiliary transfer table to facilitate moving cars in or out of the house and also to transfer materials back and forth.

For light repairs a series of long, parallel tracks connected at each end to yard leaders is in general use. These tracks should be convenient to the main car shop, planing mill, lumber yard and general stores for the car department and have space left for storage of working supplies.

A freight car repair plant covers the following facilities, viz.: Erecting or main freight car shop, planing mill, dry kiln, lumber shed, iron shed, scrap bins, etc. Also machine shop, blacksmith shop, wheel shop, pattern shop, general storehouse, power plant, etc., all of which are generally not specially assigned to the freight car department, but used conjointly for all departments of the entire plant. There is also in some cases a special freight car truck shop.

A new departure, already inaugurated on a very small number of roads, is a special shop for repairs of steel cars, with proper appliances for lifting and the necessary special tools, forges, furnaces, etc. There is no doubt that this will be an important sub-department

in the future. It is probable that power cranes and hoists of various kinds will be used more in the future, even in connection with the repairs of wooden freight cars.

There is nothing very difficult in the designing of freight car shops, except arranging the layout of the various buildings, planing mill and material yards so as to get the machines, working tracks and supply tracks in such relation to each other that the material will pass through the shops in the natural sequence of the work. It is also necessary to take care of the sawdust and shavings.

The only remaining point is the question of track spacing and it is the most important element of the track layout, both for the light repair yard and the car shop proper, and also the disposition of light narrow gage material tracks between the car tracks, cross tracks with turn-tables at proper places, or mechanical transfer devices.

One system is to space all the tracks for light repairs from 16 to 20 ft. centers, and for heavy repairs and inside the shop from 20 to 22 ft. centers, with narrow gage material tracks in each space between tracks. Another system is to group the track in pairs, about 16 to 20 ft. centers, and leave a wide passageway, 20 to 26 ft. centers, between each group, with a narrow gage service track down the passageway. A third system is to space all tracks evenly, about 20 to 22 ft. centers, and run narrow-gage tracks in every alternate space.

Many of the recent freight car shop designs have adopted the uneven spacing and grouping of tracks in pairs, viz.: Merchants' Despatch car shops at Despatch, N. Y., 1897; Missouri, Kansas and Texas, Sedalia, Mo.,

1898; Central of New Jersey at Elizabethport, N. J., 1901; New York Central at Oak Grove, Pa., 1902; and Pittsburgh and Lake Erie, McKees Rocks, Pa., 1902.

On the other hand, the even spacing has been recently adopted at the New York, New Haven and Hartford main car shops, Readville, Mass., 1901; Delaware, Lackawanna and Western main car shops, Scranton, Pa., 1902; Union Pacific, Omaha, Neb., 1902; Atchison, Topeka and Santa Fe., Topeka, Kan., 1902; Canadian Pacific, Montreal, Canada, 1902; East Los Angeles, Cal., 1903, and East Moline, Ill., 1903.

CHAPTER VI.

GENERAL SHOP STOREHOUSES.

The general storehouse for a large repair shop should be central to all departments and close to the principal departments requiring supplies. It should be connected by tracks or conveying facilities with all important departments.

Provision must be made for unloading cars with material for the storehouse and for switching and storage of cars, not ready to be unloaded at once or waiting for switch engine to take them away. Much material can be handled and stored on open platforms surrounding or adjoining the storehouse, although the tendency is especially marked in industrial plants to store all materials under cover. There should also be a number of sheds or open platforms throughout the plant, adjacent to the main buildings, such as iron sheds, lumber sheds, lumber yard, scrap bins, etc., which will be under the control of the shop storehouse department although separated from the main storehouse.

Storehouses are usually built two stories high, as there is a large amount of small material that can be stored in an upper story. Platform elevators are provided for this purpose.

In regard to class of structure, it would seem very important to make this building fireproof, yet actual practice indicates that, while brick buildings are used, the interior construction is timber, in some cases "slow burning mill construction," but generally ordinary timber construction. Many shops have small model fireproof structures for storage of patterns, but the fireproofing of the main storehouse has been omitted, pre-

sumably as a matter of economy. As explained by one official at an important new shop plant, all the attention was given at the start to the main buildings and when the storehouse was taken up money was running short and economies were necessary. As a general proposition, however, the fireproofing of the storehouse, or at least certain sections of it, would seem self-evident.

The general office of the shops is usually connected with the storehouse, built at one end of the building or on the second floor. This is not good practice, as it introduces additional fire risk. It is preferable to build a separate office. For similar reasons separate storehouses for oil, paint, varnish, etc., are always built and located so as to reduce the fire risk as much as possible.

It is difficult to establish any rule as to the proper size of a storehouse, as the conditions vary at each plant and in many cases the shop storehouse serves as a general storehouse for road and division supplies.

The following data is compiled from the best sources available.

Examples of store houses at main locomotive shops:

Michigan Central, Jackson, Mich. Old locomotive shops, remodeled 1902, and new store house built, 175' x 75', 13,125 sq. ft. Erecting pits, 30 engines, and some emergency car work, or say 430 sq. ft. per erecting pit.

Philadelphia and Reading, Reading, Pa., 1901. Erecting pits, 70. Store house, 2 floors, 70' x 100', 14,000 sq. ft., or 200 sq. ft. per erecting pit. There are no general or division supplies carried at this point.

New York Central, Depew, N. Y., 1892. Erecting pits, 48. Store house, one floor, 144' x 75', 10,800 sq. ft., or 225 sq. ft. per engine pit. There are no general or division supplies carried at this point.

Chicago, St. Paul, Minneapolis and Omaha, St. Paul, 1902. Erecting pits, 15. Store house, 60' x 150', 9,000 sq. ft., or 600 sq. ft. per erecting pit.

Penn. R. R., Juniata Locomotive Manufacturing Shops, Altoona. About 1890. One floor, 71' x 51', 3,621 sq. ft., 14 engines, or 260 sq. ft. per erecting pit.

Buffalo, Rochester and Pittsburgh, Du Bois, Pa., 1901. Fourteen engines. Store house, two floors, 60' x 120', with office in part of second floor. Say, 12,000 sq. ft., or 860 sq. ft. per erecting pit.

Great Northern, St. Paul, 1902. General store house, two story, 100' x 360', or 72,000 sq. ft. floor. Separate iron store, 100' x 200', or 20,000 sq. ft. floor.

Examples of store houses at main car repair shops:

New York, New Haven and Hartford, Readville, Mass., 1901. Standing capacity, passenger, main shop, 60 coaches; freight, main shop, 60 freight cars. Store house, 75' x 300', 22,500 sq. ft.

Lehigh Valley, General Store House, Packerton, Pa., 1899. Used for main coal car repair shops at Packerton, and general supply house for system. Two stories, 71' 1½" x 301' 1", 42,960 sq. ft.

Missouri, Kansas and Texas, Sedalia, Mo., 1898. Shops stated to employ 250 men and sufficient capacity for building 24 freight cars and 5 passenger coaches at the same time, in addition to all car repair work. Store house, 80' x 40', 3,200 sq. ft.

Examples of store houses at general repair shops:

Chicago Great Western, Oelwein, Iowa, 1899. House, 5 stories, 94' x 50', 23,500 sq. ft. for 15 erecting pits and passenger and freight departments.

Chicago, Burlington and Quincy, Hannibal, Mo., 1901. Store house 2 stories, 50' x 250' and office, or say, 22,500 sq. ft. for 10 erecting pits and passenger and freight departments.

Wisconsin Central, Fond du Lac, Wis., 1901. Store house, 50' x 350', 17,500 sq. ft. Shops expected to take care of 150 engines and 10,000 cars.

Chicago and Northwestern, Kinzie Street. Chicago. Shops taking care of about 1,100 engines and passenger and freight car departments. All store house facilities about 75,000 sq. ft.

Illinois Central, Burnside, Chicago. Store house, 2 floors, 70' x 300', 42,000 sq. ft.

New York Central, Oak Grove, Pa.. 1902. Capacity of buildings, 19 erecting pits and 60 freight cars. Store house, 75' x 250', 18,750 sq. ft.

Central of New Jersey, Elizabethport, N. J., 1901. Store house,

50′ x 300′, 15,000 sq. ft. Plant expected to take care of 450 engines, 500 coaches, 4,000 freight cars and 4,000 coal cars.

Missouri Pacific, Baring Cross, Ark., 1901. Shops expected to take care of 189 engines and passenger and freight car departments. Store house, 15,000 sq. ft.

Minneapolis and St. Louis, Cedar Lake, Minn. Extended 1902. Expected to take care of 80 engines, 65 coaches and 3,000 freight cars. Store house, 10,250 sq. ft.

Lake Shore and Michigan Southern, Collinwood, O., 1902. Capacity of buildings, 24 erecting pits, 25 coaches and 42 freight cars. Store house, 2 stories, 60′ x 302′, 36,240 sq. ft.

Pittsburgh and Lake Erie, McKees Rocks, Pa., 1902. Capacity of buildings, 24 erecting pits, 12 coaches, 78 freight cars. Store house, 15,000 sq. ft.

Chicago and Rock Island, East Moline, Ill., 1903. General repair shops. Locomotive department expected to repair 60 engines per month; 38 erecting pits. General store house, 3 stories, 100′ x 500′, total floor area, 150,000 sq. ft.

Southern Pacific, East Los Angeles, Cal., 1903. General repair shops, 22 erecting pits, 16 coaches. Storehouse, 63′ x 74′.

CHAPTER VII.

POWER PLANT AND MACHINERY.

1.—POWER AND POWER PLANT.

In regard to the power for a large repair shop, it must be conceded that electricity should be used. The testimony as to its successful installation and operation at so many plants, not only at industrial works, but also for railroad companies, should be conclusive.

Whether to use the direct or alternating current seems to be the only main question left open for discussion. There are prominent examples of both systems and strong advocates for each. The final selection will depend on the special conditions and, as a rule, largely on the views of the electrical expert employed to design the plant. The general tendency would seem to favor the alternating current as the primary current for large plants, owing to its flexibility and greater range of application to various uses independent of distance.

In regard to machine driving with electricity, the question is whether to use a separate motor for each machine or to group the machines and drive from short sections of shafting. There are extremists in both cases and plants have been turned out all group driven and others with all individual motors. The best and most conservative practice is to follow the lead of the majority of the plants and introduce a judicious combination of individual and group driving. In this case the only question open for discussion is the degree to which the group driving shall be extended, or, in other words, the minimum size of motors. The limit would seem to be, at

the present state of the art, to use no motors smaller than 5 H. P.

Practice has also indicated absolutely that it is economy at large plants to centralize all steam and electric generating machines for power and lighting, together with air compressors, pumps, water pumps, etc., in one central power house.

The committee of the American Railway Master Mechanics' Association in 1900 on the subject, "Power Transmission by Shafting vs. Electricity," reached the following conclusions:

1. In a small shop, consisting practically of one building, having an equipment of small tools for light work only, electric transmission will not be found a paying investment. In such a shop, however, an electric lighting dynamo will be a convenience, and may be utilized to run a few labor-saving electric tools, such as cylinder boring outfit, a turntable motor, etc.

2. In an extensive shop plant the installation of a central power station and electric transmission will always be found advisable, as it will not only result in the most economical system in respect to operation, but will make possible far more important shop economies, namely, an increase in quantity and quality of output and a reduction in cost of handling same.

The power station layout and building should be made so as to allow for all reasonable future requirements, and the mechanical arrangements for handling coal and ashes, pipe ducts, etc., should be arranged accordingly at the start. The actual equipment of boilers, engines, generators, pumps, etc., should be put in for present needs, leaving the balance of the floor and building ready for subsequent additions to the power plant as found necessary.

In settling on the power plant auxiliaries, care should be taken not to complicate the equipment and give greater liability for trouble and delays by the introduc-

tion of too many steam-saving appliances, unless coal is very costly. Wherever coal is comparatively cheap it is preferable to adopt a simple plant, with necessary duplicates or "spares" to fall back on in case of trouble.

In some cases the use of fuel oil or producer gas may prove more economical than coal. The steam turbine is also forging fast to the front as a live proposition for power plants. Sight should not be lost of the fact, however, that railroad shops have to be heated and that the use of exhaust steam is the most economical and best method to follow, which cannot be done advantageously with gas engines or steam turbines.

2.—MACHINERY, TOOLS AND OVERHEAD CRANES.

Evidence is accumulating daily as to the value of a full and up-to-date equipment of machinery for a shop, not only effecting economies in operation but especially also increasing the quality and quantity of the output. In railroad repair shops the question is not only to make the repairs economically, but primarily also one of speed, i. e., to get the equipment back into service, thereby not only releasing tied-up capital and restoring its earning power, but also enabling the railroad company to handle its business efficiently and promptly.

Ample machine equipment of a shop is the principal feature to insure prompt return of engines into service. On most railroads the machine equipment at the shops is inadequate or antiquated. In this respect railroad companies are far behind manufacturing plants. The success of American manufacturers over British concerns is largely attributed to the prevailing practice of American manufacturers to always have the best machinery and appliances, even if they have to scrap comparatively new machines.

The committee of the American Railway Master Machanics' Association appointed to report in 1898 on the subject of "Advantage of Improved Tools for Railroad Shops" stated:

We find that where a careful selection and proper application has been made of improved tools in shops, the saving in time over the old methods of getting out the same class of work is so great as to set aside all doubt.

Rapid strides have been made in the invention and introduction of powerful and convenient motors having electricity and compressed air to actuate them and their extended use in connection with the latest improved tools designed to work with them is strongly urged by your committee.

Mr. Wm. Forsyth has stated, "There are two ways to reduce the cost of locomotive repairs. One by the introduction of new and efficient machinery, and the other by improvements over old methods."

The speed of output of a locomotive repair shop is regulated mainly by the machine department. Unless this department is well equipped and of proper size, shopped locomotives will be constantly waiting to get into the shop, or, if there are sufficient erecting pits, will simply be stored, so to say, in the house in place of out in the open. Increased pit capacity does not mean increased shop output, unless the machine shop is able to respond to a rush and has ample equipment to keep repairs of engines on all the pits going simultaneously. It might be stated as an axiom that it is preferable to have too little pit capacity and too much machine capacity than the reverse.

Of course, the special machines in all departments must be properly balanced with reference to the expected total shop output, but, as a rule, in existing railroad shops the equipment of the machine shop is not up to the

requirements of the erecting shop and engines are kept waiting for machined parts.

There are no existing general rules as to the proportion of tools of various kind with relation to the work in different departments. This must in each case be established by observation of similar work in existing plants and suitable estimates of the new requirements.

The number of "tools per pit," i. e., number of tools in the machine shops per erecting pit, is frequently referred to as the measure of the machine facilities, compared with the erecting shop. Unless it is exactly stated by some clear definition what constitutes a separate machine tool and how to rate new and old tools, this unit of comparison is very uncertain. The proportion runs in different plants from about four to 13 tools per pit. In some very well-known shops, where the proportion is over 10 tools per pit, it is known that the machine shop never delays the work.

In a manufacturing plant the exact amount of each class of machine, smith or boiler work to be performed on a given engine can be predetermined and the ratio of total tool equipment to the desired engine output closely balanced. In railroad shops the conditions are entirely different, fluctuating and can only be averaged roughly. If equipment is not to be tied up in the shop, waiting for machine work, it is necessary to install an excess of machinery, if anything, so as to cover all possibilities and be able to meet the strain of rush times.

Mr. R. H. Soule, in a communication to the Railway Age of September 5, 1902, summarizes this entire subject as follows:

"The basis of all locomotive repair shop design should be to so proportion the machine shop floor space to the number of erecting

shop stalls, as to secure the maximum output of repaired engines, which conversely means the minimum period of keeping each locomotive out of service. The art of railway shop design has not yet been developed to the point where we can turn to accepted formulas for deducing such proportions and the best we can do is to follow the precedents of what is believed to be good practice; but even then the solution is not easy, for the ratios deduced from, say, a dozen first-class shops will be found to vary widely, and the figures thus obtained have to be supplemented by personal investigation, with the result that a great many variable factors must be taken into account, such as shop organization, character of tool equipment, extent to which labor-saving devices (such as cranes, etc.) are provided and used, character of labor employed (proportions of skilled and unskilled, etc.), character of locomotive equipment (whether light or heavy, etc.). But the net result of it all is, that a locomotive repair shop carefully thought out, planned, erected and equipped to-day, ought to turn out at least one-third more engines per year than a shop of the same floor area built ten years ago; and further, a shop of the same floor area built ten years from now ought to yield a still further increase of output, as the individual electric driving of machine tools will probably be highly perfected by that time. It is said that most of our machine tool-makers are at work on revised designs of tools, with a view to making them enough heavier and stiffer to yield the maximum output which will be made possible by the combined use of the individual electric drive (with a wide range of speed variations), and improved tool steels giving heavy cuts."

In preparing a list of machines tools for a proposed large locomotive repair shop of an Eastern trunk line, the following proportions were established after a very careful study of the subject. While the list is somewhat dependent on the personal equation of the motive power official, still the results arrived at will be of interest, viz.:

Cutting tools, 26 per cent.; turning tools, 52 per cent.; drills, 13 per cent.; miscellaneous, 9 per cent. Total, 100 per cent.

The cutting tools were sub-divided as follows: Planers, 50 per cent.; shapers, 20 per cent.; slotters, 20 per cent.: milling, 10 per cent. Total, 100 per cent.

The turning tools were sub-divided as follows: Lathes, 80 per cent.; boring mills, 15 per cent.; grinding, 5 per cent. Total, 100 per cent.

Owing to the recent advancement in the manufacture of tool steels and the more rigid construction of special machines for using such improved steels at higher speeds and with a greater range of variability in speeds, it can be reasonably assumed that the output from a given number of modern machines properly equipped and driven will be larger than in the older class of shop tools usually found in railroad shops. The assumptions as to increased output per machine unit must, however, be conservative and ascertained from a practical view of shop operations. The increased speed or depth of cut of a modern machine does not necessarily mean increased output in units, as the increased size of the locomotive parts to be machined, as compared with the smaller parts of older rolling stock, may require all of the increased efficiency of the new tool to turn out one part in the same time as on the old machine. Thus to turn a 10-in. axle will require a more efficient machine than to turn an old-style 7-in. axle in the same time on an old machine, and yet the output of the machine in each case is one axle. Similarly, the increased power of a 400-ton wheel-press, as compared with, say, a 200-ton wheelpress, does not necessarily affect the output, which is simply one wheel, the difference being in the size of the part handled. That a note of warning is necessary not to hastily assume that heavier and speedier tools mean invariably increased output is indicated by the fact that an experienced shop designer advocated recently the cutting down of machine shop space to two-thirds the proportion in older layouts owing to the expected in-

creased output per machine. Such sweeping assumptions will not hold, taking all classes of machinery and shop operations into account. Many new tools installed in a shop simply take the place of old tools too light for the modern heavy work without necessarily increasing the total unit output.

Finally, attention should be called to the necessity of introducing the best labor-saving contrivances for reducing the cost of handling heavy parts, not only in the erecting shop, but in the machine shop, boiler shop and around the shops and yard. Manufacturing plants generally, and also British and Continental railroad shops, are far ahead of the general American practice in this respect. During the last fifteen years, however, compressed air appliances and electric cranes have been largely introduced in American railroad shops, and it is gratifying to see the growing tendency in this direction, so that to-day a shop is not considered up-to-date unless it has electric overhead cranes, pneumatic hoists and transfer and lifting devices at every desirable point in the buildings and shop yards.

A committee of the American Railway Master Mechanics' Association reported in 1900 that "The introduction of overhead traveling cranes at the Baldwin Locomotive Works, in Philadelphia, affected a saving of 80 laborers in the erecting shop; in the wheel shop the labor force was cut from 40 laborers to 6 laborers, and in the frame shop the laboring force was cut down 60 per cent."

Mr. W. N. Forney stated in 1892: "Testimony to show the economy of time and labor in erecting locomotives by means of traveling cranes might be extended almost indefinitely. After diligent inquiry the writer has failed

to find anyone who has had experience in their use who has not been an earnest advocate of them. So far as convenience or facility of doing work is concerned, other things being equal, it makes no difference whether erecting tracks are longitudinal or transverse."

CHAPTER VIII.

STRUCTURAL WORK OF BUILDINGS AND AUXILIARY FEATURES.

1.—STRUCTURAL WORK OF BUILDINGS.

The character of the buildings of a railroad repair shop and the class of structural materials employed should correspond to the size and use of each building. Generally speaking, for large shop buildings brick walls are preferred, although where a steel skeleton structure is required for the support of high roofs or heavy crane runways and an abundance of side light is essential, so that the brick walls are simply curtain walls between the steel supports, then it is very desirable to consider carefully the merits of the so-called "factory plan" of using all iron and glass side walls. In such a case the brick side walls stop at the lower window sill. In many cases, especially in industrial plants, panels or horizontal bands of the side walls between the windows are covered with concrete slabs fastened to the steel frame, making a cheaper although not as ornamental a construction as brick filling supported on an iron frame. The Erie at Dunmore, Pa., and the Central of New Jersey at Elizabethport, N. J., have recently built all concrete shop buildings.

The foundation walls should be concrete or rubble masonry. The roof should be structural steel and the sheathing of boards, or, preferably, reinforced concrete slabs. Roofing for flat roofs should be preferably a first-class grade of tar and gravel or slag roofing in preference to tin; on steep slopes slate is better than tin or tile.

The floor in boiler, blacksmith, casting and similar departments should be cinders, and in all other buildings preferably wood on concrete bed. Where rough work is done, use yellow pine or oak plank, but for a first-class shop, like a machine shop, coach shop and even in the erecting shop, a top floor of maple is being used very extensively in sections of the country where a second-grade maple flooring is comparatively cheap. The concrete is frequently a tar concrete; in other cases a layer of tar or tar and sand mixture on top of stone or cinder concrete is used as a damp course under the floor planks. High grades of tarred felt or waterproof papers are also used as a damp course under the flooring. Boiler room floors should be preferably brick or concrete and paint shop floors concrete or asphalt.

Concrete floors are used at some shop systems with good results. The top should be wood floated, not metal floated. Concrete floors should not be used where men have to stand at benches or machines. Wood floors are preferable at such points or wooden racks on top of the concrete floor.

In regard to fire insurance, it will be found on investigation that practically fireproof rating can be obtained in all metal-working shops with brick walls, unprotected iron columns and trusses, solid plank floors on concrete sand or cinder bed, even if windows and doors are of wood, provided wooden purlins and roof sheathing are not used; in other words, provided tiling, re-enforced concrete or hollow brick are laid on the iron roof framing direct. This will increase the roof load and the cost, and estimates should be made to ascertain whether the decreased premium payment for the building and contents would offset the increased interest on the first cost.

It is not merely a question of whether the railroad company can cover itself by insurance for direct loss by fire, but the safer structure will protect the company from indirect losses, such as interference with its business while adjusting a fire loss and rebuilding, loss of equipment and machinery that cannot be readily replaced, etc. The arguments in favor of first-class fireproof construction are particularly pertinent for companies who carry their own fire risks.

A timber roof covering offers a large area for a fire to spread, and it is very difficult to stop. Similarly there is considerable fire risk even in a solidly bedded timber floor, in case it gets oil soaked. A fire once started on the floor would spread rapidly. Intercepting strips of concrete, as, for instance, the use of concrete between the rails of tracks inside of the building, have been advocated so as to confine fires running along oil-soaked floors to certain restricted zones.

When the contents of a shop are of a combustible nature, such as in car shops, planing mills, etc., the use of fireproof construction is less indicated. In some cases "mill construction" will be warranted and will assist in reducing the insurance premium. Sprinkling systems, on which insurance companies lay so much stress, are practically ineffective in large, high, one-story shop buildings, especially where the upper space has to be left clear for crane service.

In designing roof spans, etc., care should be taken to specify exactly what weights it may be desired to hang from the trusses, not only permanently, but such as the shop men or repair men may be liable to hang on the trusses, such as in lifting crabs or motors off of overhead cranes.

In regard to lighting, dependent on conditions, the glass for side lights are double-thick plain glass or fine-ribbed "factory glass" to break the direct rays of the sun. Skylights and monitor glazing are generally wired glass. Wire netting underneath glass is not a desirable construction. Recently at a number of large plants "translucent fabric" has been used for top lights. The lighting at night is done by means of arc lights for general illumination and incandescent lamps for individual lighting.

Heating in almost all large industrial, municipal and railroad buildings is generally done by the hot-blast system, in which fans throw air across heating coils, heated by exhaust steam from the central power plant, and the heated air is conveyed by large, properly proportioned ducts, suspended from the roof or placed underground, to the various outlets throughout the buildings. There are, however, a number of large plants using the hot water system, notably the large new plant of the Allis-Chalmers Company at West Milwaukee. For smaller buildings and offices heating by direct radiation is used.

Additional structural features requiring attention are the sewerage, sub-soil drainage, so as to draw the water from around the pits and underground ducts and pipe passages, water supply, fire protection appliances, ventilation, sanitary arrangements, closets, lavatories, lockers, piping distribution for hot water, compressed air, wiring, removal of smoke at testing pits, removal of sawdust and shavings in woodworking departments, etc.

The architectural treatment should be neat and plain, corresponding to the character of the various buildings, and depend on the size and mass of the various buildings for effect rather than on minor architectural embellishments and details which are out of place and not warranted.

2.—AUXILIARY FEATURES AND APPLIANCES.

The study for the track layout of a railroad repair shop should not only cover the building and immediate needs, but should be designed to be capable of such reasonable enlargements as may seem requisite for the future. Tracks should not only be supplied for the actual working tracks, but all parts of the plant should be brought under one general track scheme, so as to facilitate and simplify all movements. In some parts of the plant narrow-gage tracks for push car service will be required. But, in general, the main shop tracks for moving materials on cars should be preferably standard gage.

The only class of switching engine that should be used around a large shop plant is an electric storage or a compressed air locomotive, thereby reducing all risk from fire and allowing these engines to run freely in the lumber yard or inside the buildings, and permitting very short curves to be turned.

Ample yard tracks should be provided for storing crippled cars or engines waiting to be repaired and for condemned equipment to be sold or broken up.

It is desirable to settle in the preparation of the general scheme where lumber yards, scrap bins, miscellaneous storage of old materials, etc., are to be located and to allow ample space for such purposes.

The shop grounds should be enclosed by a fence, with entrances for the men.

If any extra money is available for a first-class office building, it should be mainly expended on the interior and not on the exterior.

There should be good wagon roads throughout the principal passageways between the shops, all track crossings boarded over, so as to enable wagon deliveries to be

made at the various shop buildings, but more particularly so as to allow of the free passage of local fire engines in case of fire. This is a provision that is neglected at many shops, even where there is an organized local fire department. Fire hydrants and hose-cart houses should be scattered liberally throughout the plant.

Finally it is desirable to urge once more the importance of having the entire layout of buildings and yard facilities capable of easy extension from time to time, and, further, that it is seldom that a railroad company finds it has too much land on hand. Ample land should be bought in the start before improvements on adjoining properties spring up and make it impossible to make additional purchases.

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Am. Eng.—American Engineer and Railroad Journal.
Eng. News.—Engineering News.
Eng. Rec.—The Engineering Record.
Loc. Eng.—Locomotive Engineering.
R. R. Car.—Railroad Car Journal.
R. R. Eng.—Railroad and Engineering Journal.
R. R. Gaz.—The Railroad Gazette.
Ry. Age—The Railway Age.
Ry. Eng.—Railway Engineering and Mechanics.
Ry. Mach.—Railway Machinery.
Ry. M. M.—Railway Master Mechanic.
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ILLUSTRATIONS.

GROUP I.

CROSS LOCOMOTIVE ERECTING SHOP WITH TRANSFER TABLE AT GENERAL REPAIR SHOPS WHERE ONE TRANSFER TABLE SERVES ALL DEPARTMENTS.

GROUP II.

CROSS LOCOMOTIVE ERECTING SHOP WITH TRANSFER TABLE AT PLANTS WITH SEPARATE LOCOMOTIVE DEPARTMENT.

GROUP III.

CROSS LOCOMOTIVE ERECTING SHOP WITH CRANE FOR TRAVERSING ENGINES.

GROUP IV.

Longitudinal Locomotive Erecting Shop.

GROUP V.

Main Car Shops.

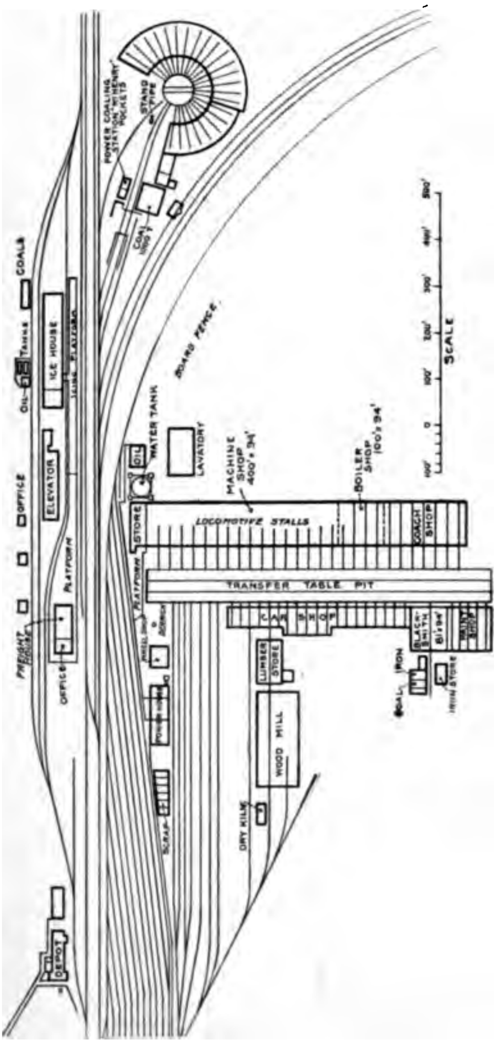

Fig. 1—General Repair Shops, Chicago Great Western, Oelwein, Iowa.

One transfer table for all departments, 15 locomotive erecting pits, new shops, 1899.

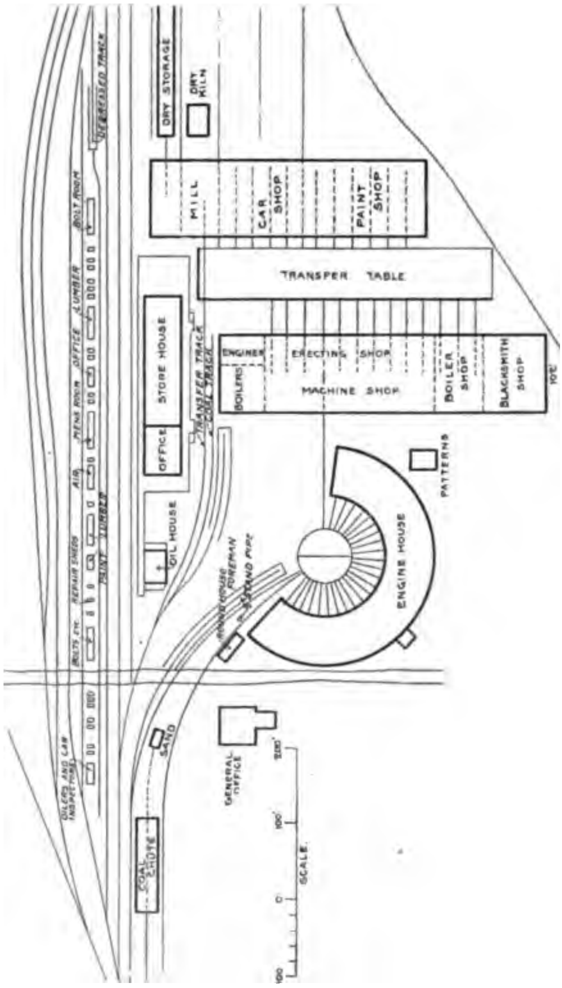

FIG. 2—GENERAL REPAIR SHOPS, CHICAGO, BURLINGTON & QUINCY (HANNIBAL & ST. JOSEPH), HANNIBAL, MO.

One transfer table for all departments, 10 locomotive erecting pits, new shops, 1901.

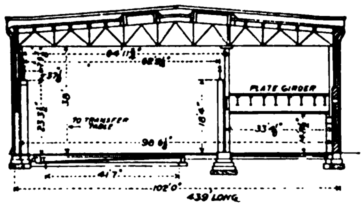

FIG. 3—CROSS-SECTION OF MAIN LOCOMOTIVE SHOP, C. B. & Q., HANNIBAL.

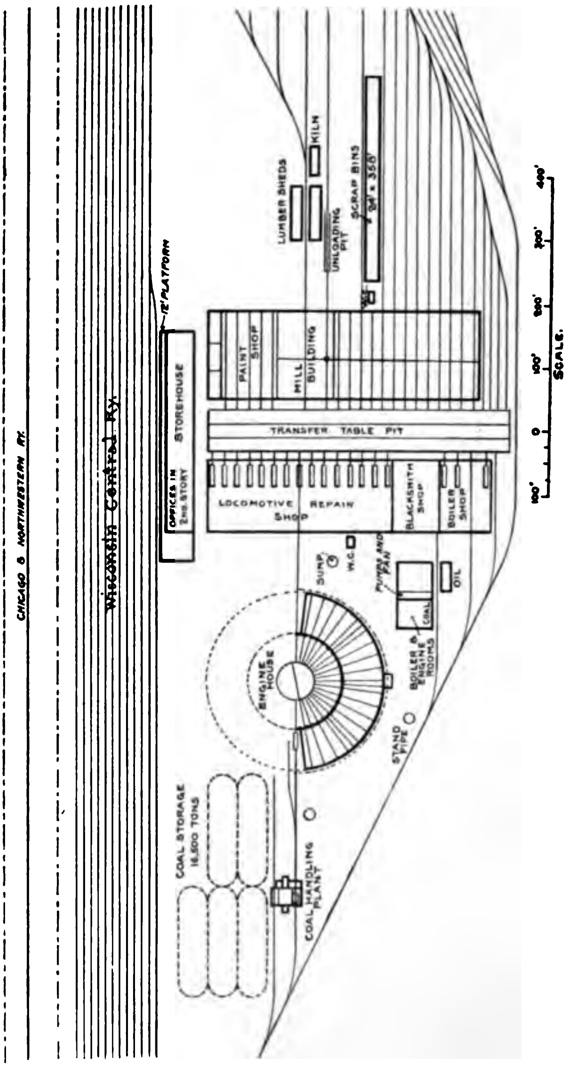

FIG. 4—GENERAL REPAIR SHOPS, WISCONSIN CENTRAL, FOND DU LAC, WIS.
One transfer table for all departments, 15 locomotive pits, new shops, 1901.

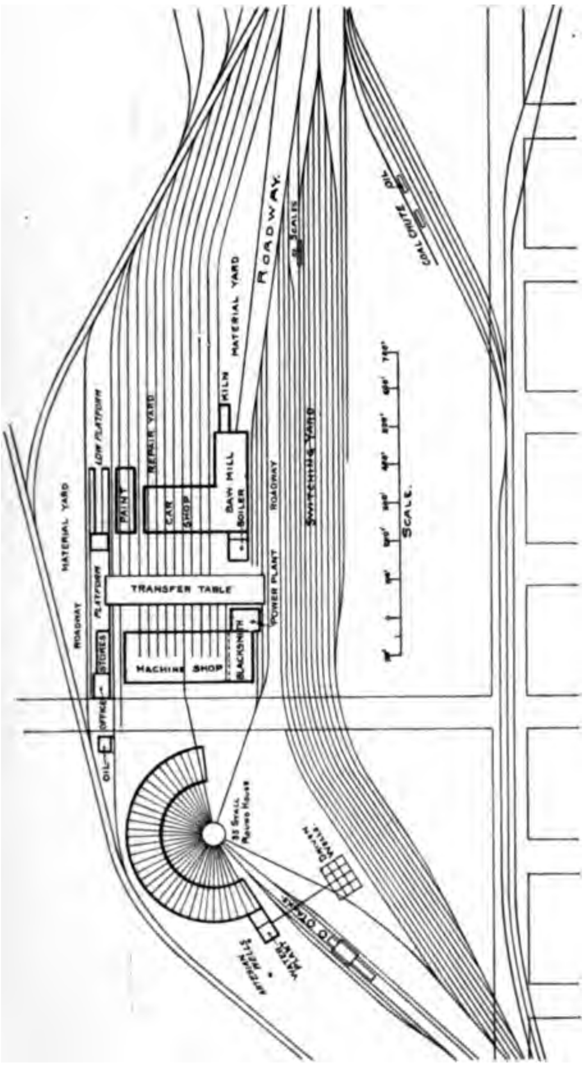

FIG. 5—GENERAL REPAIR SHOPS, COLORADO & SOUTHERN, DENVER, COL.

One transfer table for all departments, 9 locomotive erecting pits, new shops, 1901.

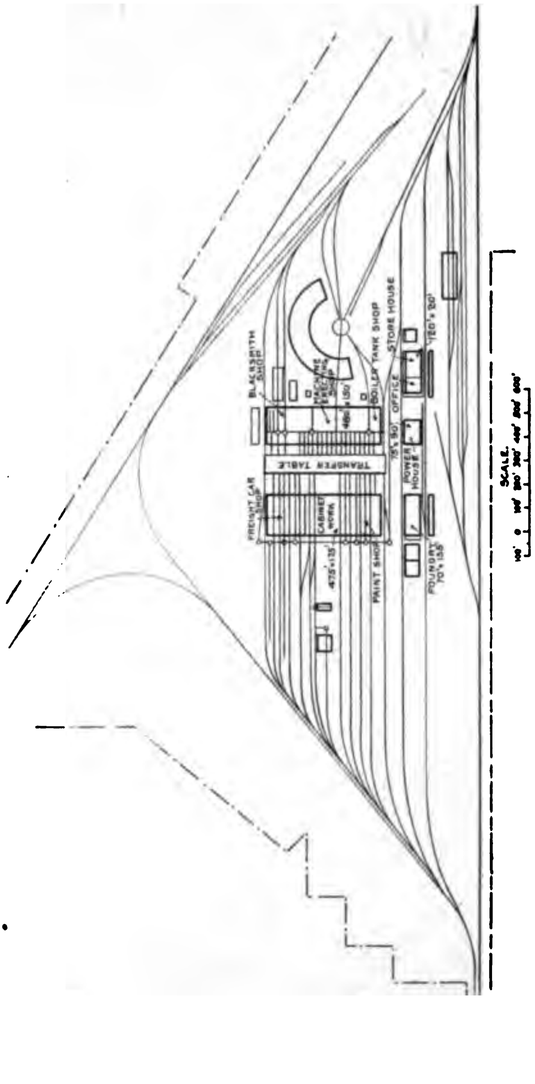

FIG. 6—GENERAL REPAIR SHOPS, OREGON SHORT LINE, POCATELLO, IDAHO.

One transfer table for all departments, 10 locomotive erecting pits, new shops, 1902.

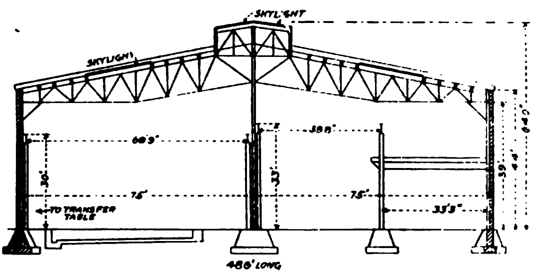

FIG. 7—CROSS-SECTION OF MAIN LOCOMOTIVE SHOP, OREGON SHORT LINE, POCATELLO.

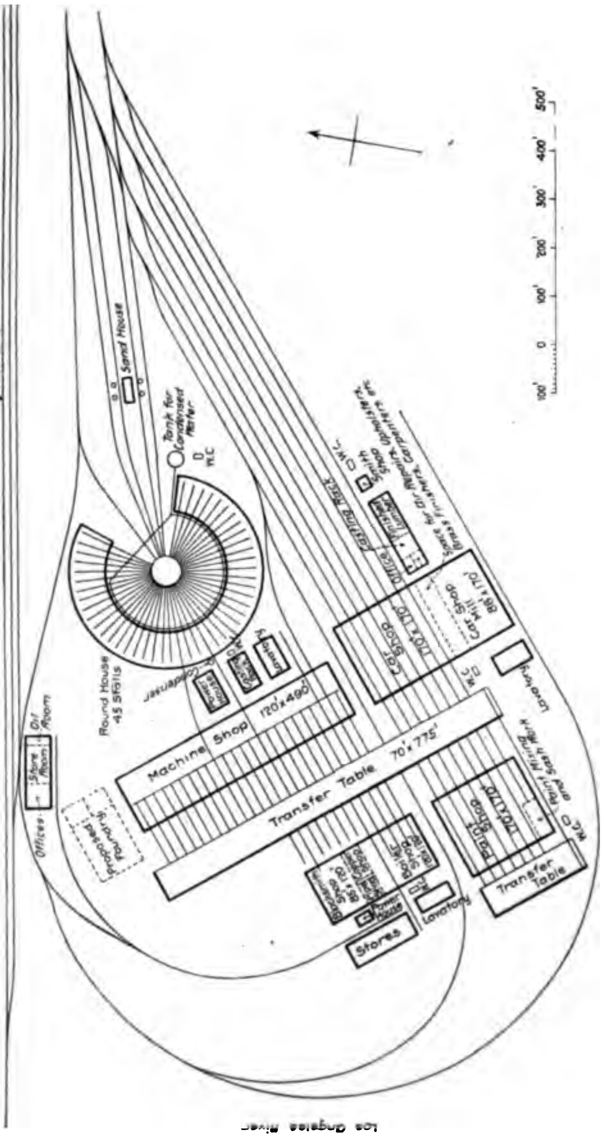

FIG. 8—GENERAL REPAIR SHOPS, SOUTHERN PACIFIC, EAST LOS ANGELES, CAL.
One transfer table for all departments, 22 locomotive erecting pits, new shops, 1903.

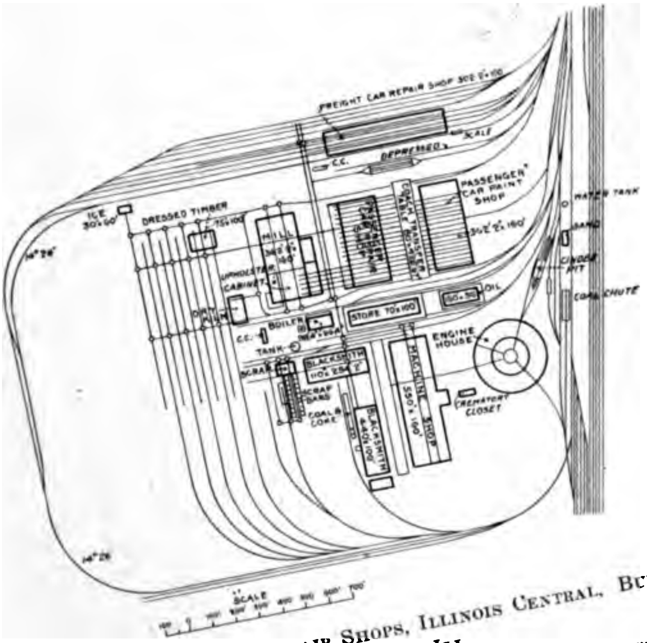

Fig. 9—General Repair Shops, Illinois Central, Burnside. Chicago, Ill.

Cross locomotive erecting shop with transfer table, 25 erecting pits. Transfer table passenger shop. Longitudinal freight car shop. New shops, 1892.

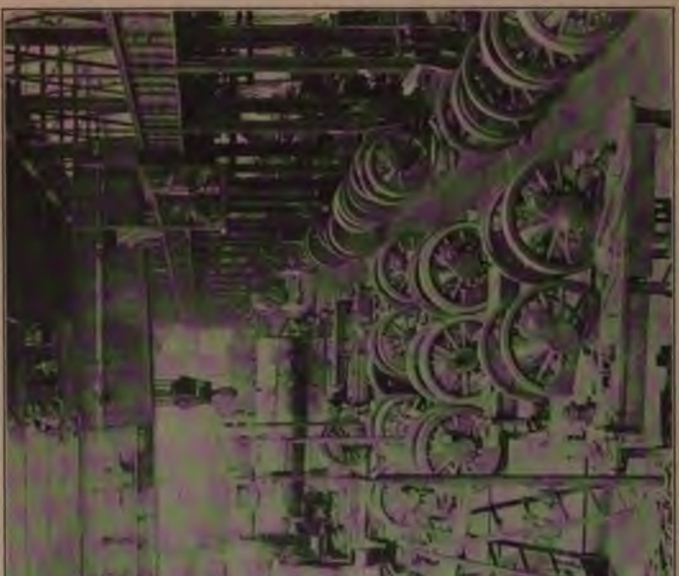

FIG. 10—MAIN LOCOMOTIVE SHOP, ILLINOIS CENTRAL, BURNSIDE, CHICAGO.

100-ton Shaw crane in erecting shop.

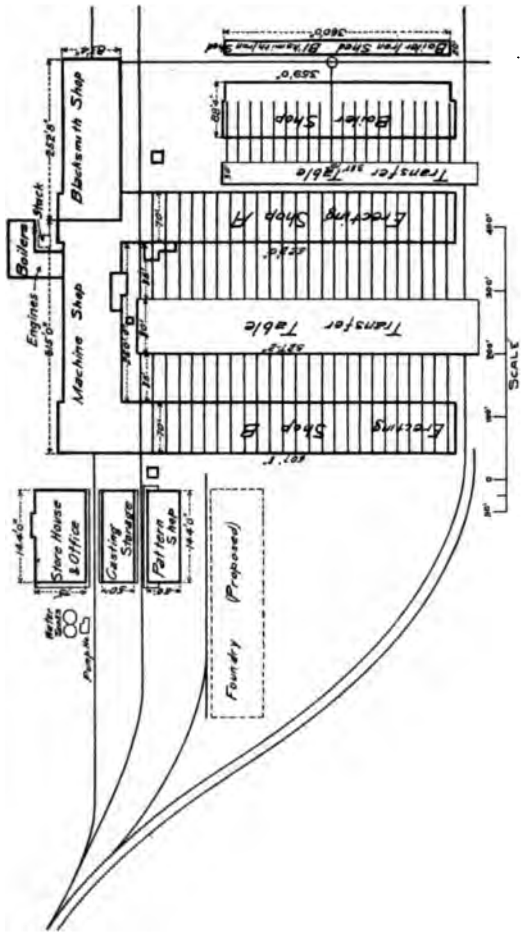

FIG. 11—LOCOMOTIVE REPAIR SHOPS, NEW YORK CENTRAL & HUDSON RIVER, DEPEW, N. Y.
Cross locomotive erecting shop with transfer table, 48 erecting pits, new shops, 1892.

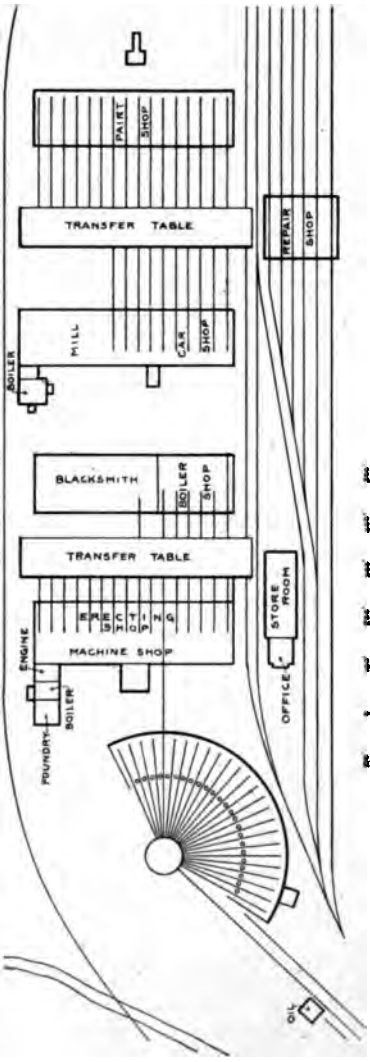

FIG. 12—GENERAL REPAIR SHOPS, EAST TENNESSEE, VIRGINIA & GEORGIA, KNOXVILLE, TENN.

Cross locomotive erecting shop with transfer table, 16 erecting pits. Transfer table passenger car shop. Longitudinal freight car shop. New shops, 1893.

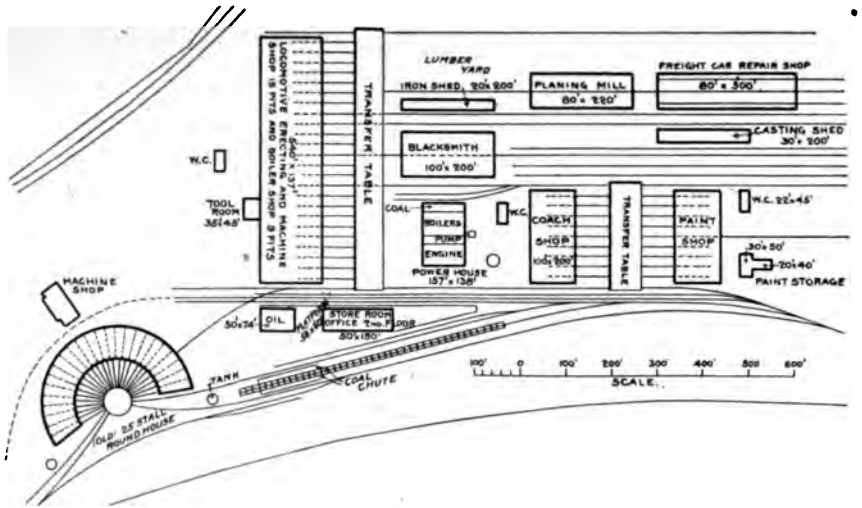

FIG. 13—GENERAL REPAIR SHOPS, ST. LOUIS, IRON MOUNTAIN & SOUTHERN, BARING CROSS, ARK.

Cross locomotive erecting shop with transfer table, 15 erecting pits. Transfer table passenger car shop. Longitudinal freight car shop. New shops, 1901.

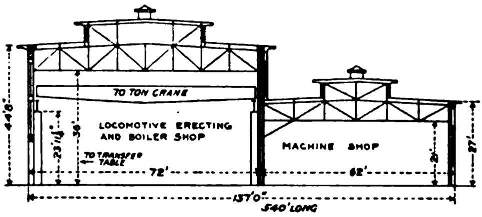

FIG. 14—CROSS-SECTION OF MAIN LOCOMOTIVE SHOP, ST. L. I. M. & S., BARING CROSS.

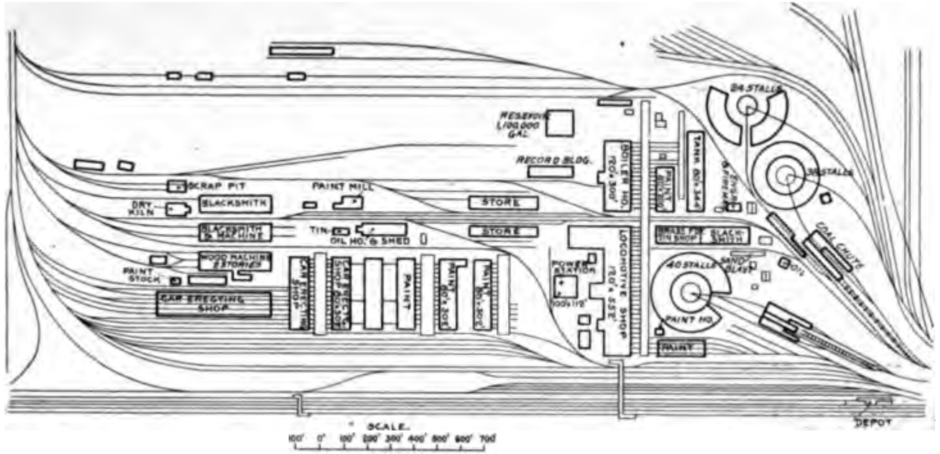

FIG. 15—GENERAL REPAIR SHOPS, CHICAGO & NORTH WESTERN, KINZIE STREET, CHICAGO, ILL.

Cross locomotive erecting shop with transfer table, 25 erecting pits. Transfer table passenger car shop. Transfer table freight car shop. Old shops, extended 1901, when a new longitudinal freight car shop added.

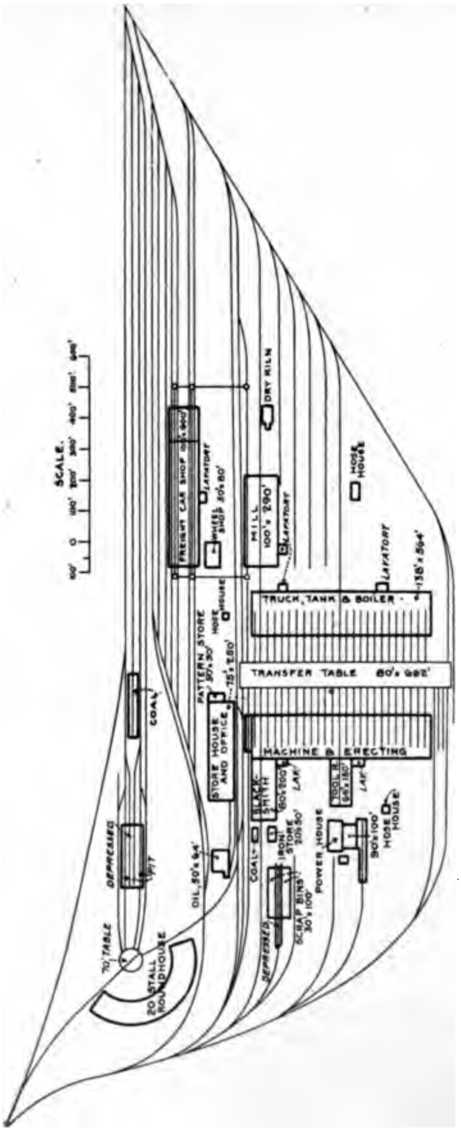

FIG. 16—GENERAL REPAIR SHOPS, NEW YORK CENTRAL & HUDSON RIVER, OAK GROVE, PA.
Cross locomotive erecting shop with transfer table, 25 erecting pits. Longitudinal freight car shop. No passenger car shop. New shops, 1902.

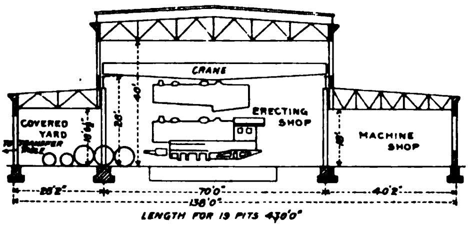

FIG. 17—CROSS-SECTION OF MAIN LOCOMOTIVE SHOP, N. Y. C., OAK GROVE.

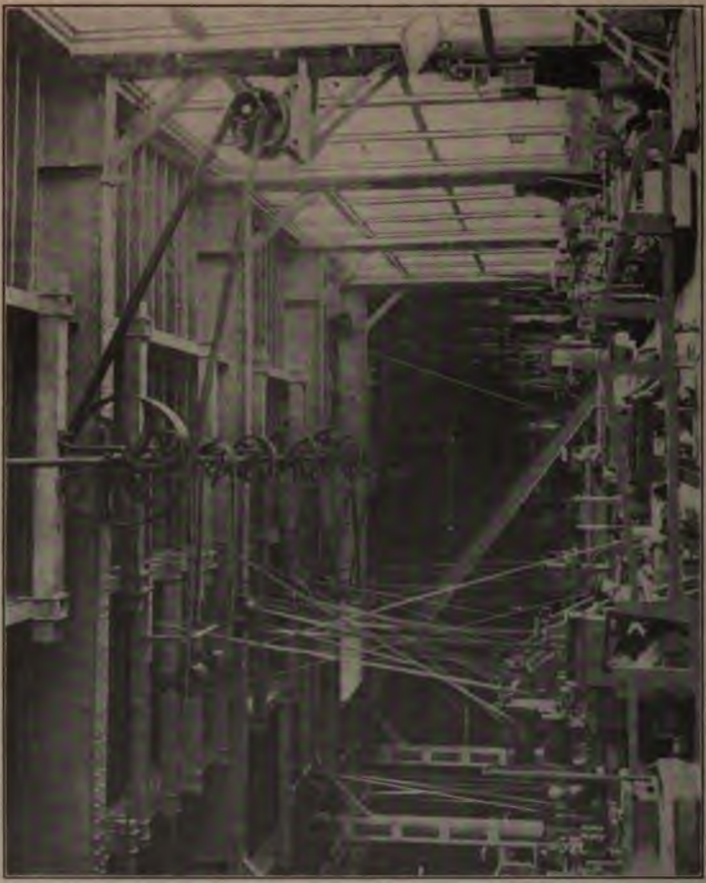

FIG. 20—MACHINE SHOP, C., M. & ST. P., WEST MILWAUKEE.
Showing method of driving a group of tools with a 30-H.P. motor.

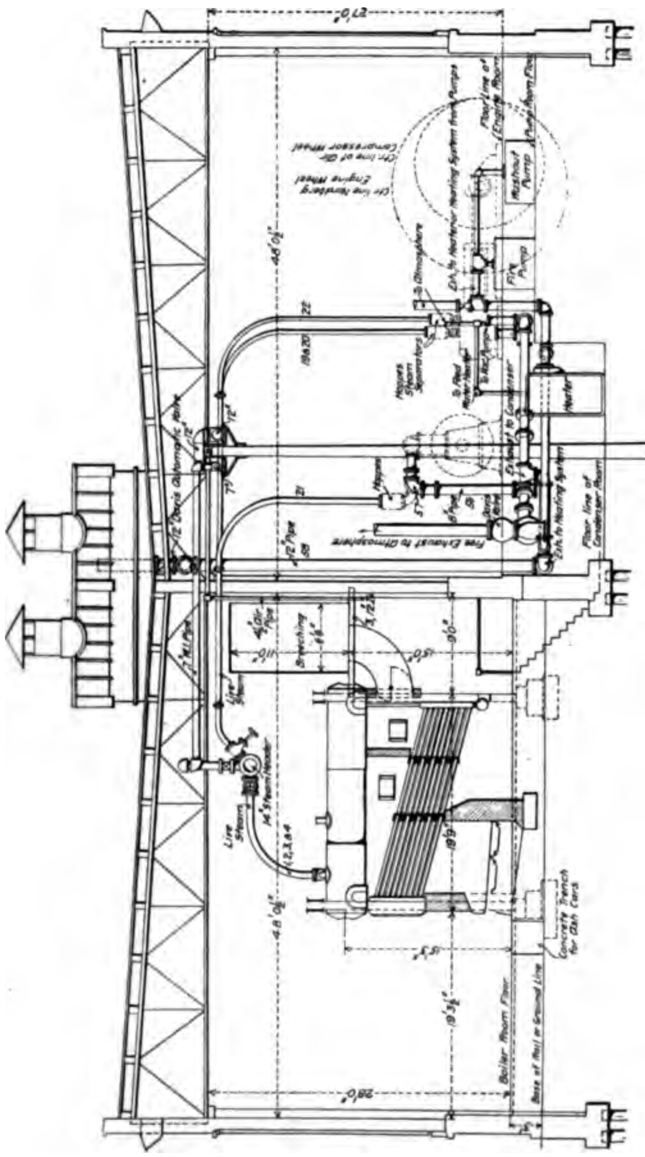

FIG. 21—CROSS-SECTION OF POWER HOUSE, C., M. & ST. P., WEST MILWAUKEE.

FIG. 22—OVERHEAD PIPE LINES AND 200,000 GALLON STEEL STORAGE TANK, C., M. & ST. P., WEST MILWAUKEE.

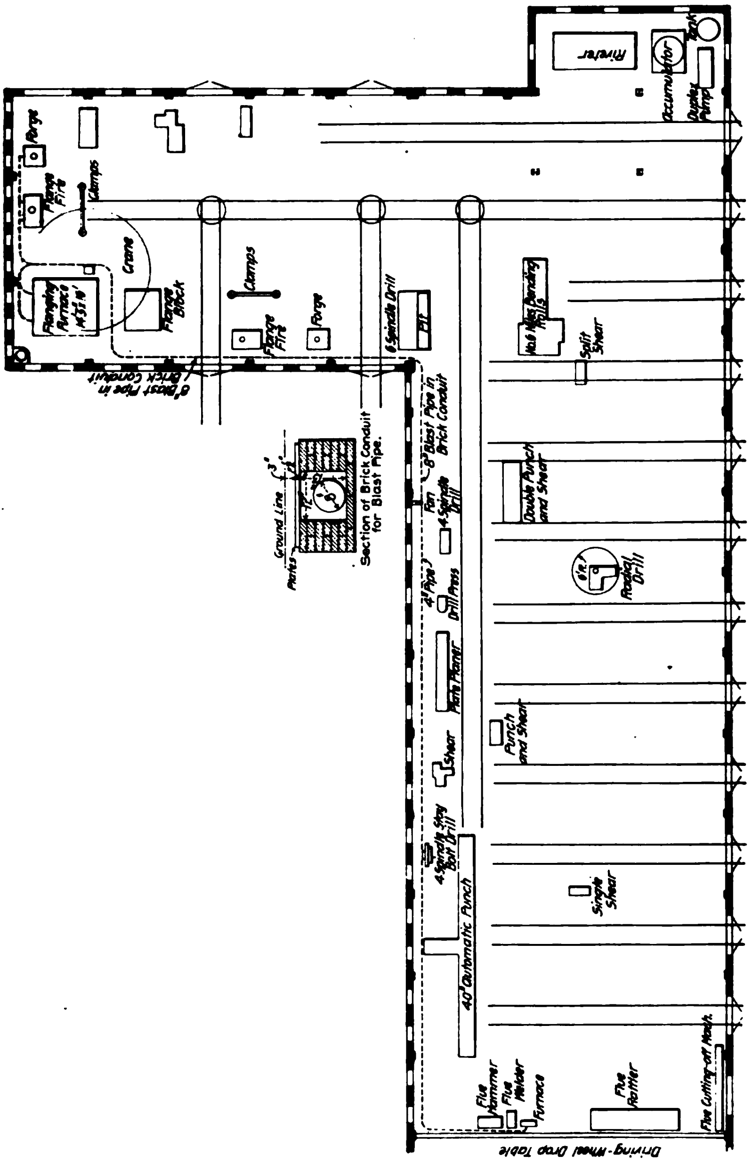

FIG. 23—PLAN OF BOILER SHOP, C., M. & ST. P., WEST MILWAUKEE.

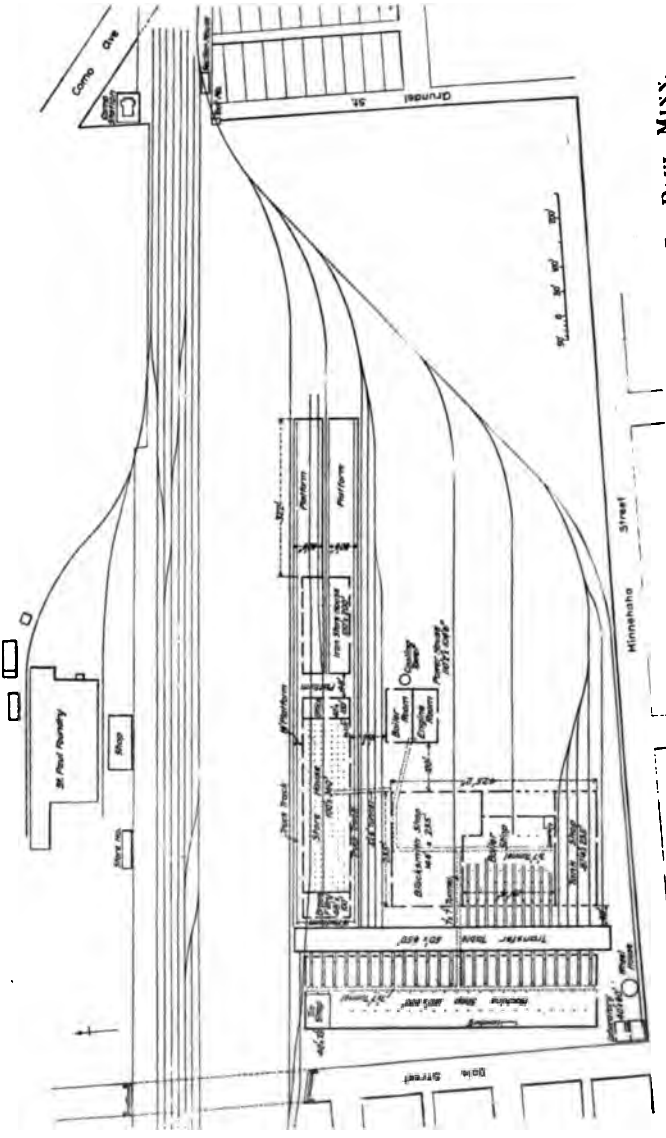

FIG. 24—LOCOMOTIVE REPAIR SHOPS, GREAT NORTHERN. DALE STREET, ST. PAUL, MINN.
Cross locomotive erecting shop, with transfer table, 25 erecting pits. New shops, 1902.

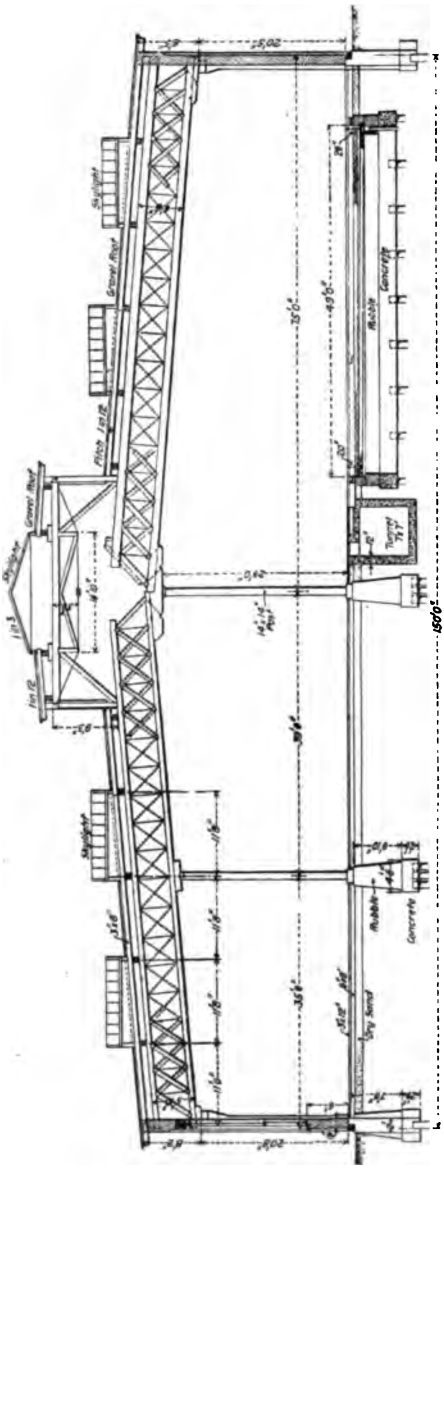

FIG. 25—CROSS SECTION OF MAIN LOCOMOTIVE SHOP, GREAT NORTHERN, ST. PAUL.

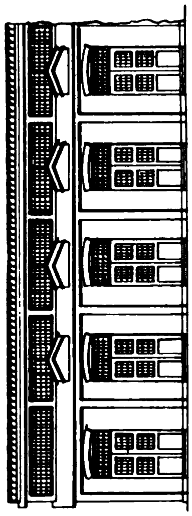

Fig. 26—Side Elevation Towards Transfer Table of Main Locomotive Shop, Great Northern, St. Paul.

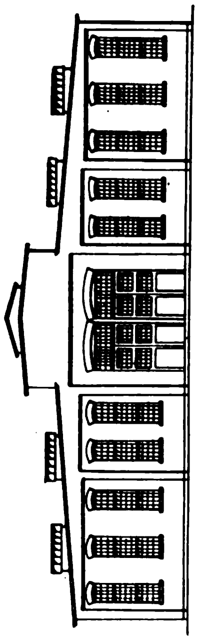

Fig. 27—End Elevation of Main Locomotive Shop, Great Northern, St. Paul.

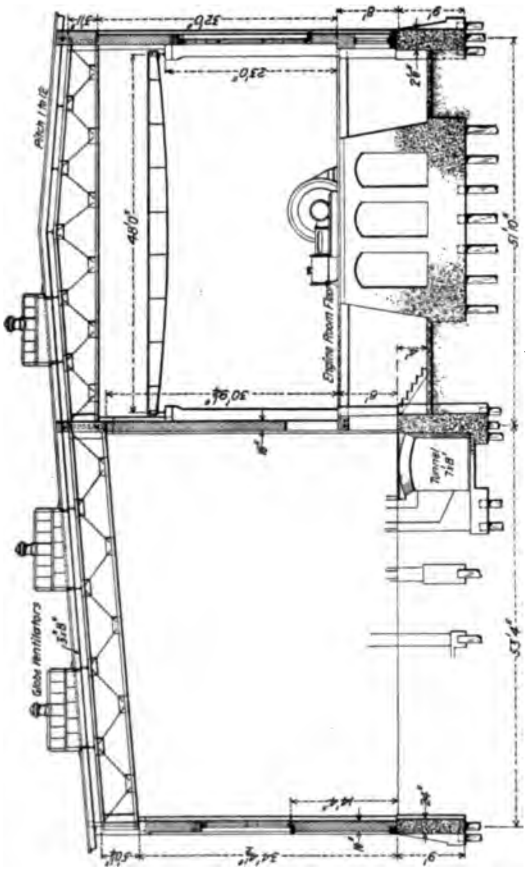

FIG. 28—CROSS SECTION OF POWER HOUSE, GREAT NORTHERN, ST. PAUL.

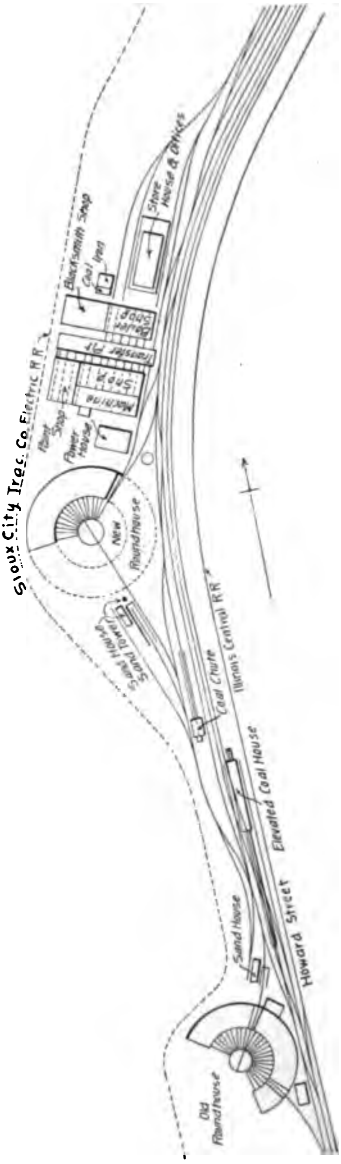

FIG. 29—LOCOMOTIVE REPAIR SHOPS, CHICAGO, ST. PAUL, MINNEAPOLIS & OMAHA, SIOUX CITY, IOWA.

Cross locomotive erecting shop with one transfer table for all buildings, 8 locomotive erecting pits. New shops. 1903.

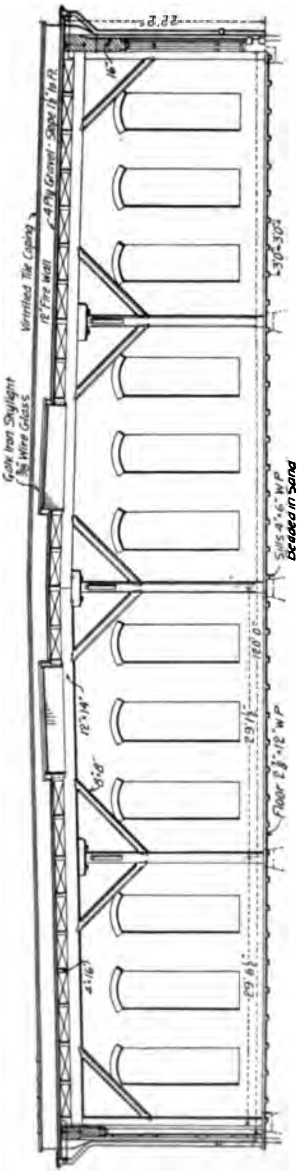

Fig. 30—Cross Section of Main Locomotive Shop, St. P., M. & O., Sioux City.

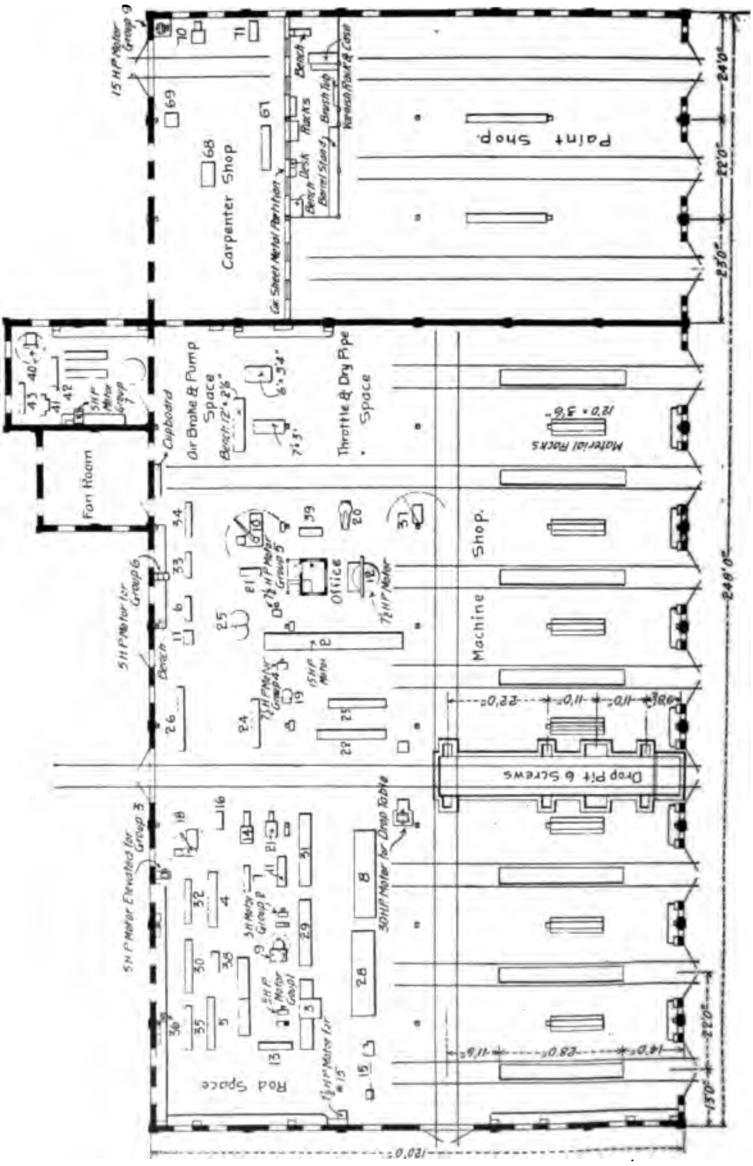

FIG. 31—PLAN OF MAIN LOCOMOTIVE SHOP, ST. P., M. & O., SIOUX CITY.

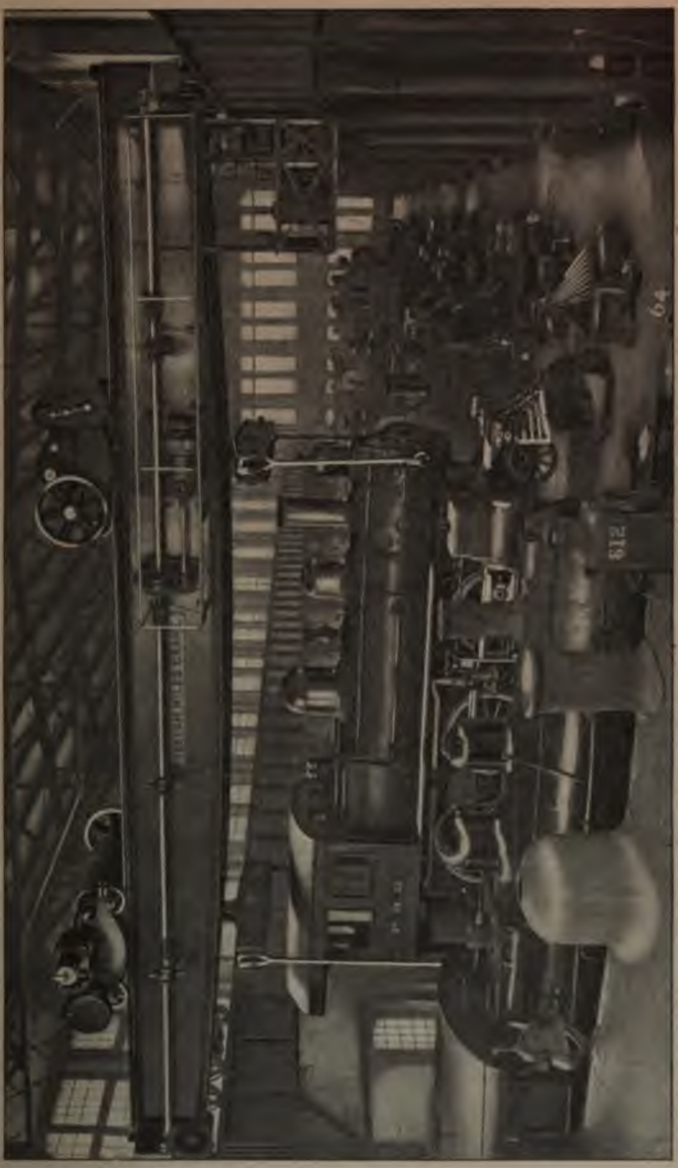

FIG. 32—GENERAL REPAIR SHOPS, PENNSYLVANIA, MEADOWS SHOPS, JERSEY CITY, N. J.
Erecting shop, with transfer table (125-ton Niles crane). Old shops, remodeled 1902.

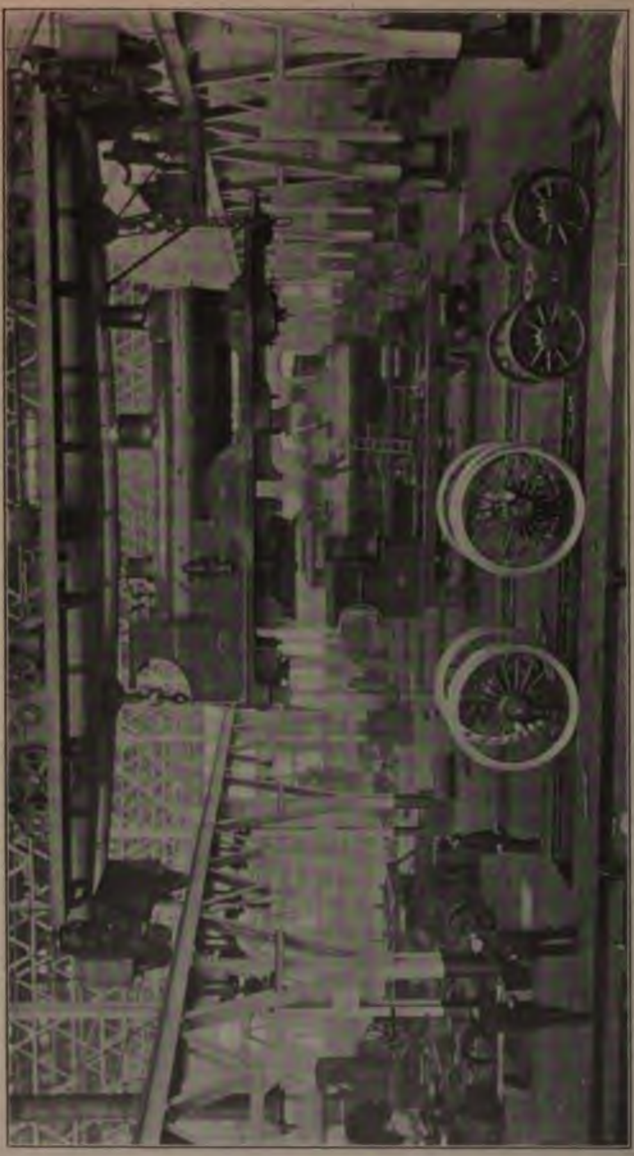

FIG. 33—LOCOMOTIVE ERECTING SHOP, GREAT NORTH OF SCOTLAND RAILWAY, INVERURIE, SCOTLAND, ENGLAND.

Cross locomotive erecting shop with crane for traversing engines. There are three erecting shops and a boiler shop similarly arranged. Electric double crab cranes, 60 tons for engines and 15 tons for boilers. New shops, built about 1900.

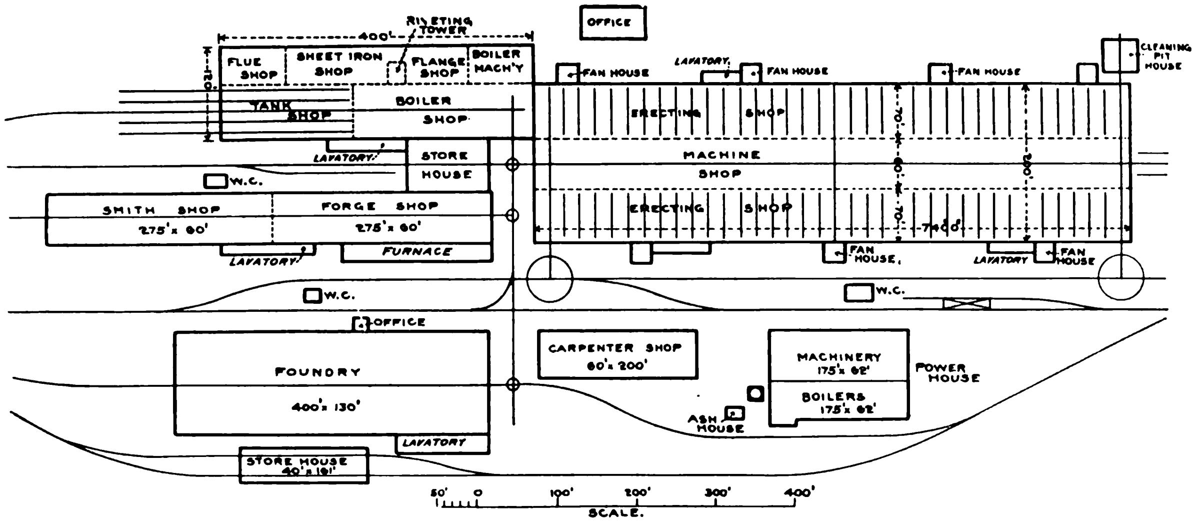

FIG. 34—LOCOMOTIVE REPAIR SHOPS, PHILADELPHIA & READING, READING, PA.

Cross locomotive erecting shop with crane for traversing engines, 70 erecting pits. New shops, 1901.

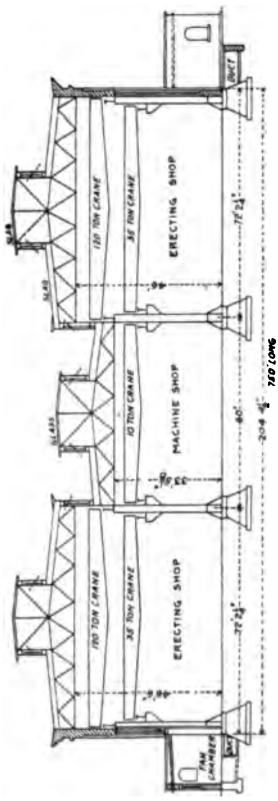

FIG. 35—CROSS SECTION OF MAIN LOCOMOTIVE SHOP, P. & R., READING.

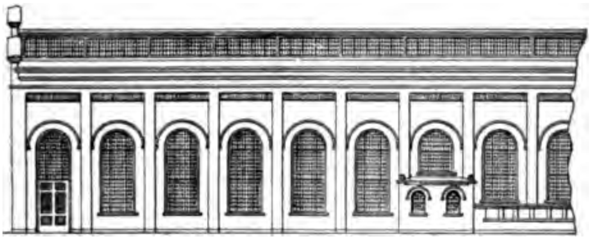

FIG. 36—SIDE ELEVATION OF MAIN LOCOMOTIVE SHOP, P. & R., READING.

FIG. 37—END ELEVATION OF MAIN LOCOMOTIVE SHOP, P. & R., READING.

FIG. 38—MAIN LOCOMOTIVE SHOP, P. & R., READING.

120-ton Niles crane on upper level and two 35-ton Niles cranes in erecting shop.

FIG. 39—MAIN LOCOMOTIVE SHOP, P. & R., READING.

10-ton Niles crane in machine shop.

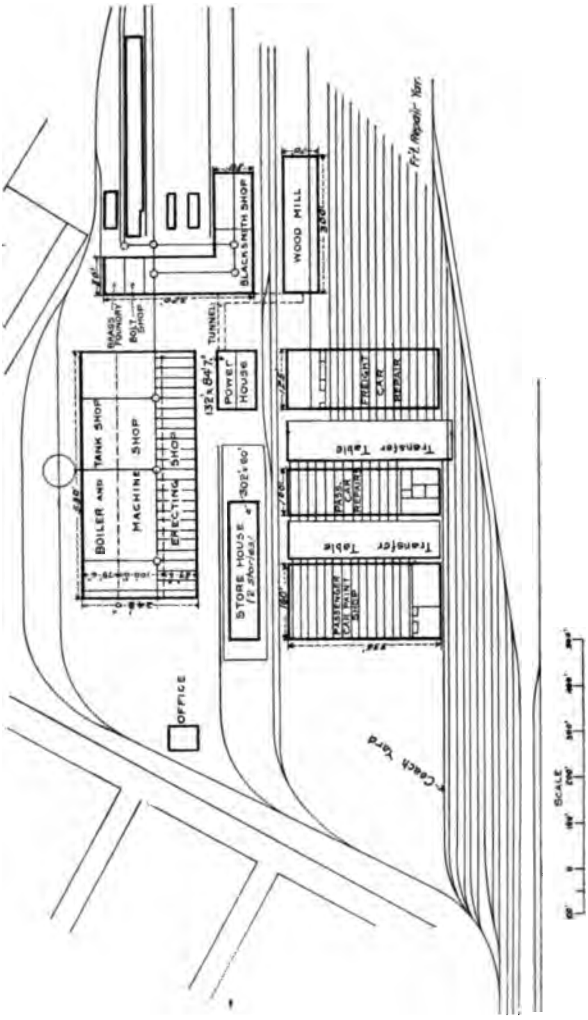

FIG. 40—GENERAL REPAIR SHOPS, LAKE SHORE & MICHIGAN SOUTHERN, COLLINWOOD, O.

Cross locomotive erecting shop with crane for traversing engines, 24 erecting pits. Transfer table passenger car shop. Transfer table freight car shop. New shops, 1902.

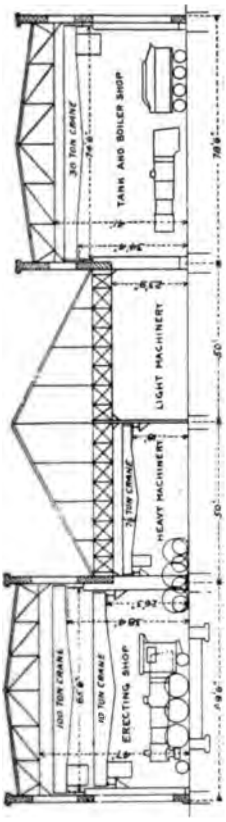

FIG. 41—CROSS SECTION OF MAIN LOCOMOTIVE SHOP, L. S. & M. S., COLLINWOOD.

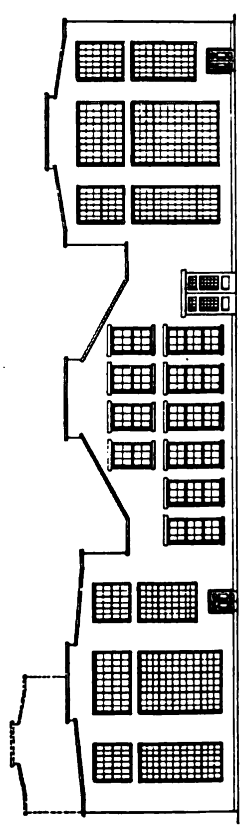

FIG. 42—END ELEVATION OF MAIN LOCOMOTIVE SHOP, L. S. & M. S., COLLINWOOD.

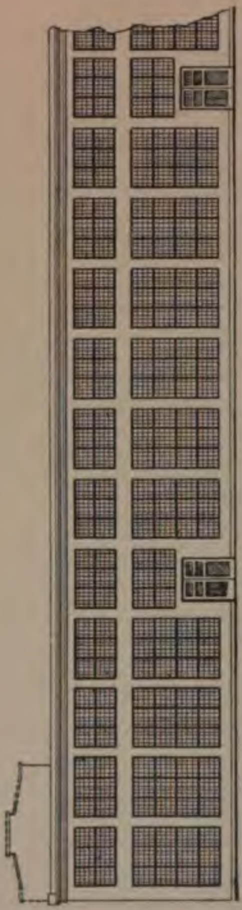

FIG. 43—SIDE ELEVATION OF MAIN LOCOMOTIVE SHOP, L. S. & M. S., COLLINWOOD.

FIG. 44—MAIN LOCOMOTIVE SHOP, L. S. & M. S., COLLINWOOD.

FIG. 45—MAIN LOCOMOTIVE SHOP, L. S. & M. S., COLLINWOOD.

100-ton Niles crane in erecting shop.

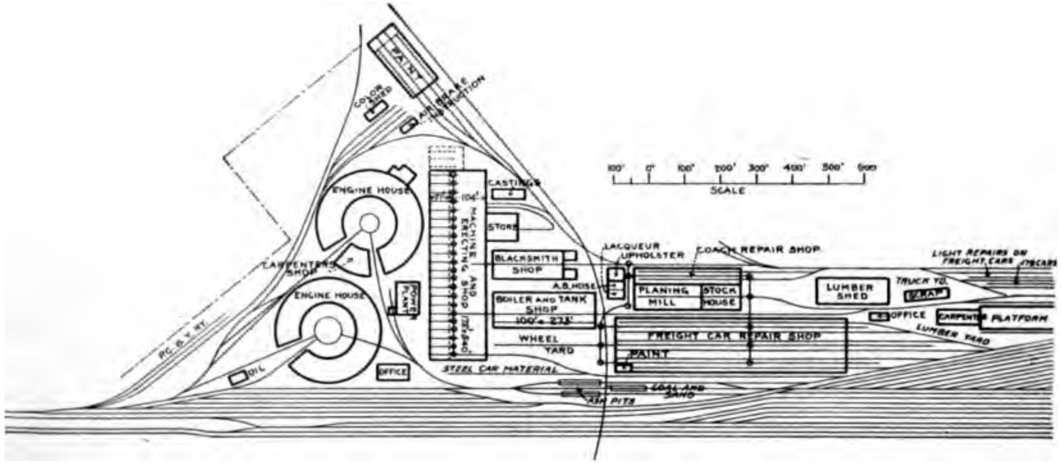

FIG. 46—GENERAL REPAIR SHOPS, PITTSBURGH & LAKE ERIE, MCKEES ROCKS, PITTSBURGH, PA.

Cross locomotive erecting shop with crane for traversing engines. 24 erecting pits. Longitudinal passenger car shop. Longitudinal freight car shop. New shops, 1902.

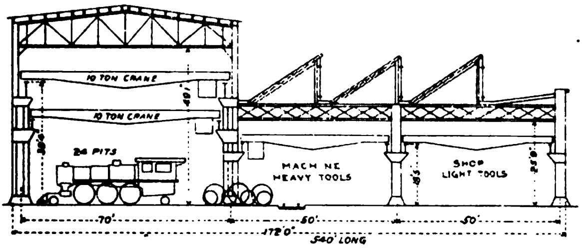

Fig. 47—Cross Section of Main Locomotive Shop, P. & L. E., McKees Rocks.

Fig. 48—Locomotive Erecting Shop, P. & L. E., McKees Rocks.

FIG. 49—BOILER AND TANK SHOP, P. & L. E., McKEES ROCKS.

Fig. 50—Blacksmith Shop, P. & L. E., McKees Rocks.

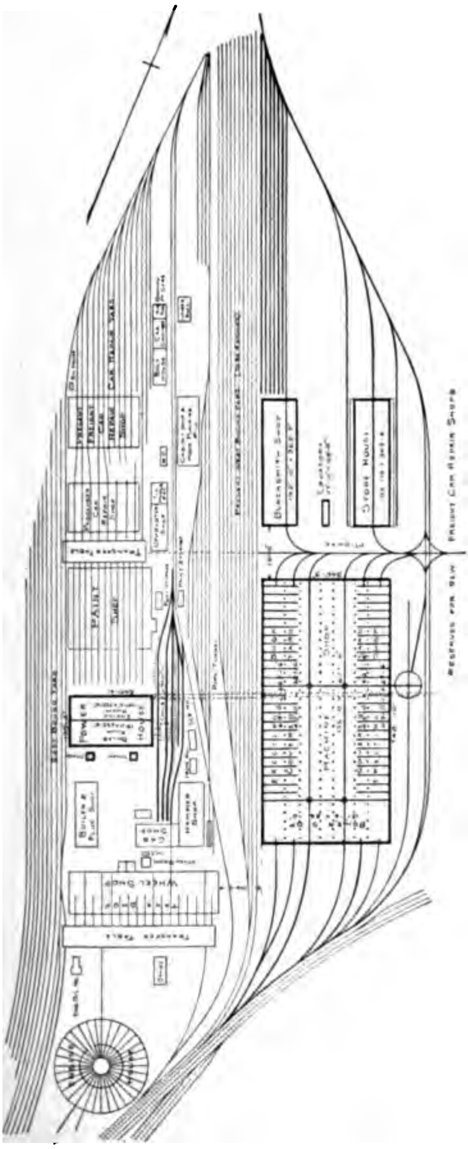

FIG. 51—GENERAL REPAIR SHOPS, LEHIGH VALLEY, SAYRE, PA.

Cross locomotive erecting shop with crane for traversing engines, 18 erecting pits. Transfer table passenger car shop. Longitudinal freight car shop. Old shops, extended 1903.

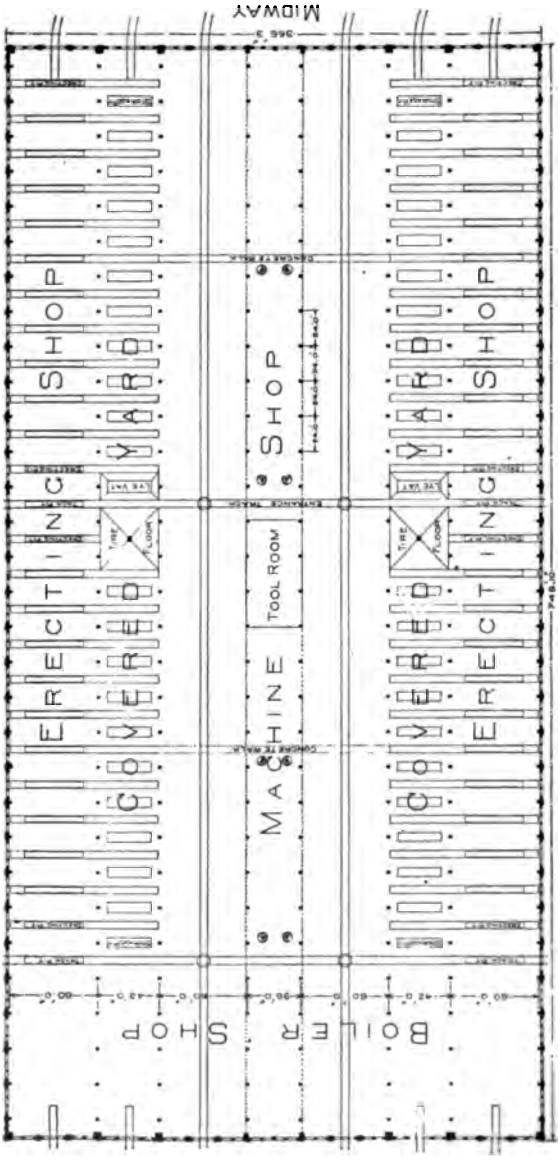

FIG. 52—PLAN OF MAIN LOCOMOTIVE SHOP, LEHIGH VALLEY, SAYRE.

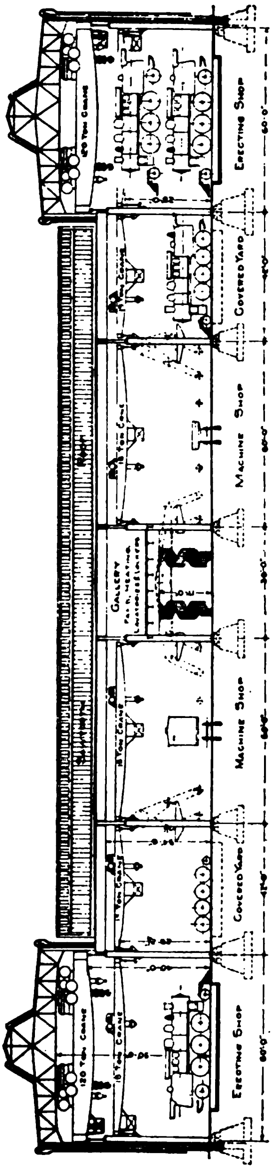

Fig. 53—Transverse Cross Section of Main Locomotive Shop, Lehigh Valley, Sayre.

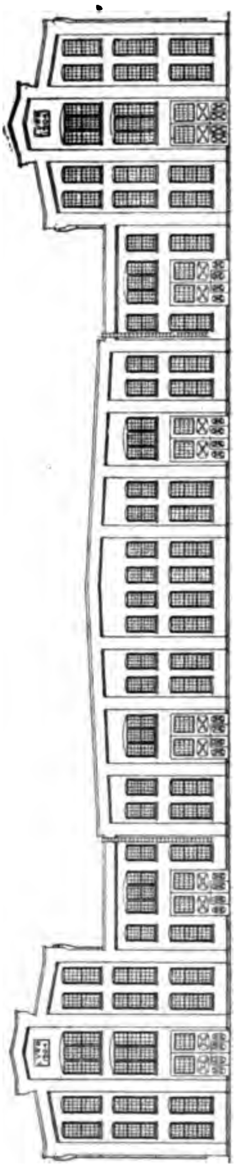

Fig. 54—End Elevation of Main Locomotive Shop, Lehigh Valley, Sayre.

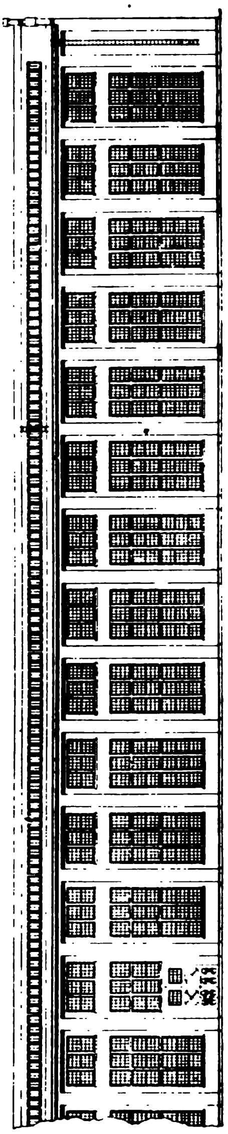

FIG. 55—SIDE ELEVATION OF MAIN LOCOMOTIVE SHOP, LEHIGH VALLEY, SAYRE.

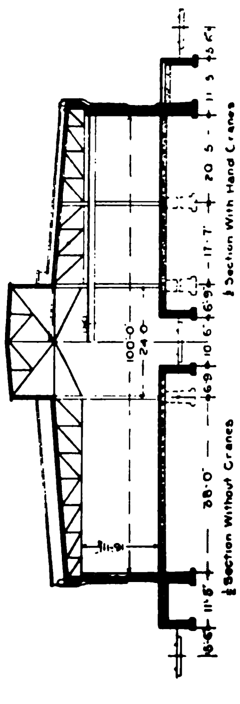

FIG. 56—TRANSVERSE CROSS SECTION OF STORE HOUSE, LEHIGH VALLEY, SAYRE.

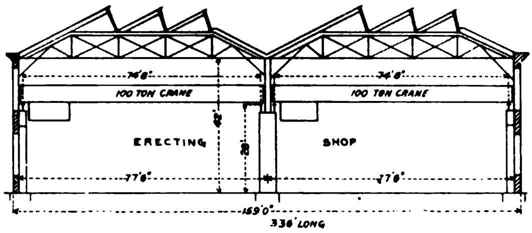

FIG. 57—CROSS SECTION OF CROSS ERECTING SHOP, BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA, PA.

Cranes for traversing engines. Installed 1890.

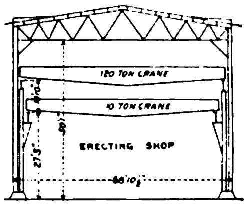

FIG. 58—CROSS SECTION OF CROSS ERECTING SHOP, BROOKS LOCOMOTIVE WORKS, DUNKIRK, N. Y.

Cranes for traversing engines. Installed 1899.

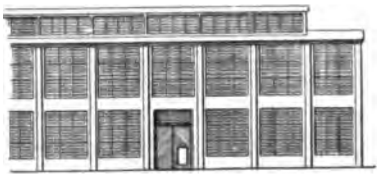

FIG. 59—SIDE ELEVATION OF ERECTING SHOP, BROOKS LOCOMOTIVE WORKS, DUNKIRK, N. Y.

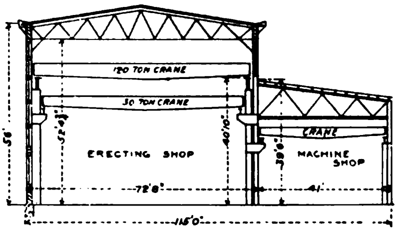

FIG. 60—CROSS SECTION OF CROSS EECTING SHOP, RICHMOND LOCOMOTIVE WORKS, RICHMOND, VA.

Cranes for traversing engines, installed 1902.

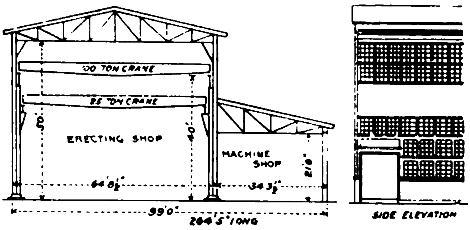

FIG. 61—CROSS SECTION AND SIDE ELEVATION OF CROSS ERECTING SHOP, ROGERS LOCOMOTIVE WORKS, PATERSON, N. J.

Cranes for traversing engines, installed 1902.

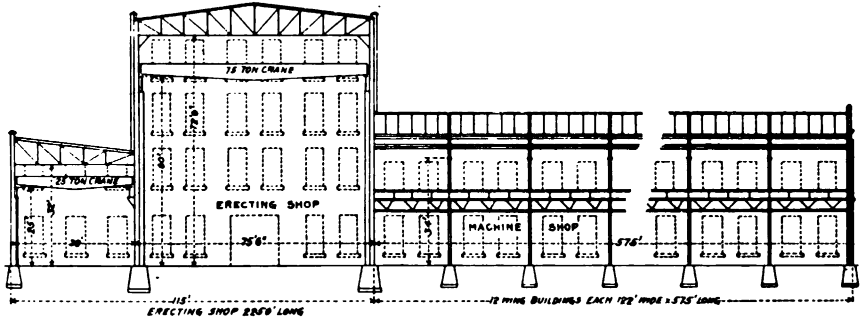

FIG. 62—CROSS SECTION OF ERECTING SHOP AND LONGITUDINAL SECTION OF MACHINE SHOP, ALLIS-CHALMERS COMPANY, MILWAUKEE, WIS.

Erecting shop, 75'x2256', and 72' high under truss, with 12-wing machine shop buildings, each 122'x575', leading into one side of the erecting shop, and a shipping house, 39'x2256', on the other side of erecting shop. Traveling cranes over 66 ft. Yards between all wing buildings. New shops 1902.

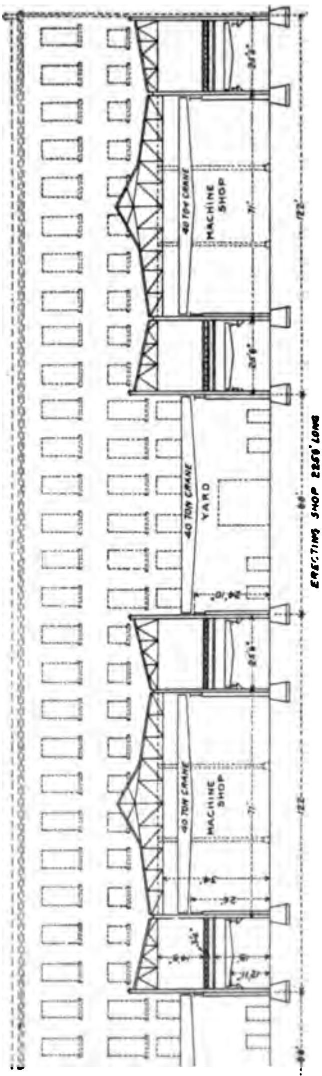

FIG. 63—CROSS SECTION OF MACHINE SHOPS LEADING INTO ERECTING SHOP, ALLIS-CHALMERS, MILWAUKEE.

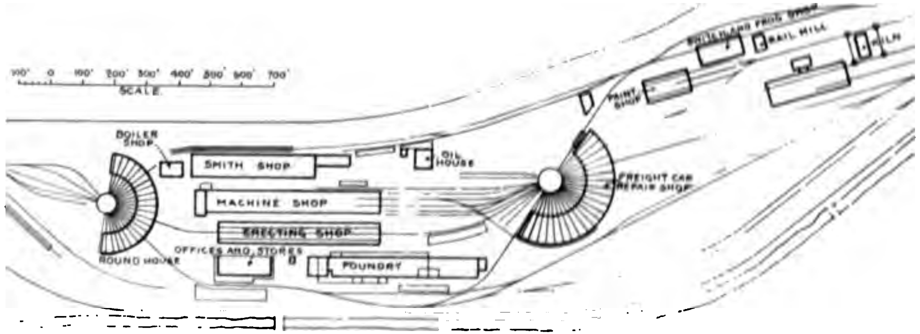

FIG. 64—GENERAL REPAIR SHOPS, NORFOLK & WESTERN, ROANOKE, VA.

Longitudinal locomotive erecting shop. Car repairs made in roundhouse. Old shops, built 1883, remodeled 1901.

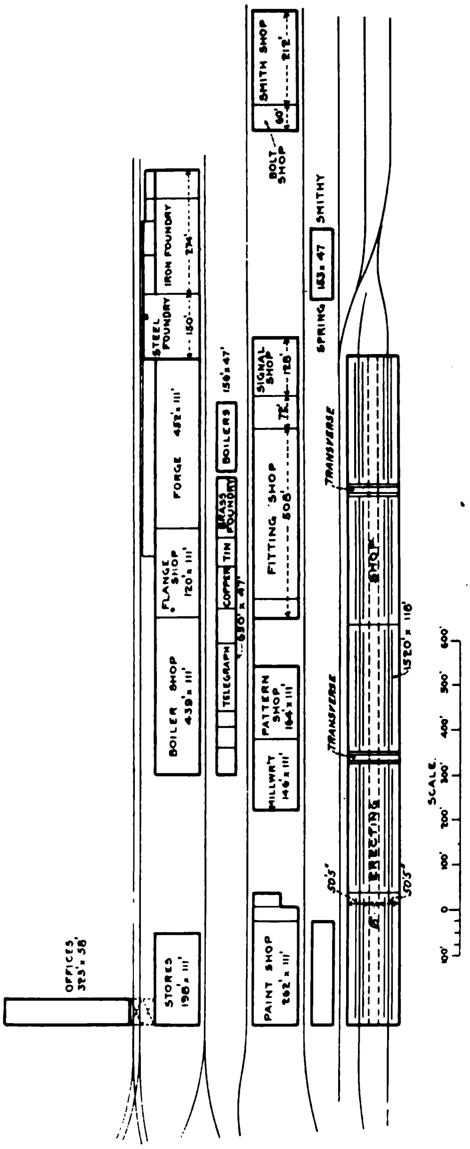

Fig. 65—Locomotive Repair and Manufacturing Shops, Lancashire and Yorkshire Railway, Horwich, England.

Longitudinal layout, built 1887 to 1892 and notable for great size of the plant. Longitudinal locomotive erecting shop, 1,520 ft. long, with two transfer tables. The principal machine work is done in the "Fitting Shop."

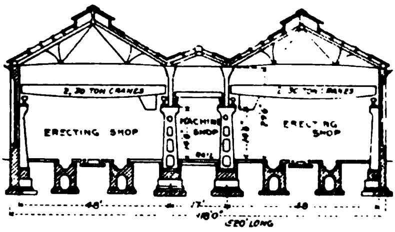

FIG. 66—CROSS SECTION OF LOCOMOTIVE ERECTING SHOP, LANCASHIRE AND YORKSHIRE, HORWICH, ENGLAND.

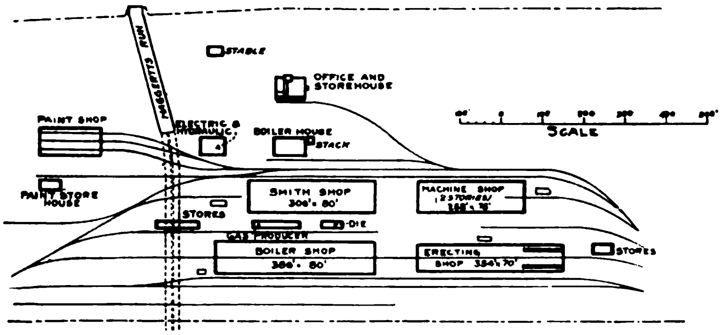

FIG. 67—LOCOMOTIVE MANUFACTURING SHOPS, PENNSYLVANIA, JUNIATA, ALTOONA, PA.

Longitudinal locomotive erecting shop, capacity about 14 engines. Illustration shows the shop layout as built new about 1890. Extensions made in 1903.

FIG. 68—ERECTING SHOP, PENNSYLVANIA, JUNIATA, ALTOONA.

Two 65-ton Shaw cranes in extension of shop, built in 1902.

FIG. 69—ERECTING SHOP, PENNSYLVANIA, JUNIATA, ALTOONA.

Two 35-ton Morgan cranes in old shop, built about 1890.

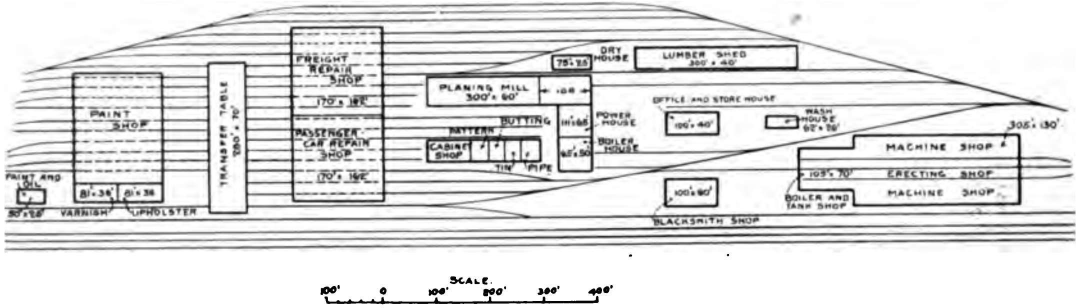

FIG. 70—GENERAL REPAIR SHOPS, BOSTON AND MAINE, CONCORD, N. H.

Longitudinal locomotive erecting shop, capacity about 12 engines. Transfer table passenger car shop. Transfer table freight car shop. New shops, 1897.

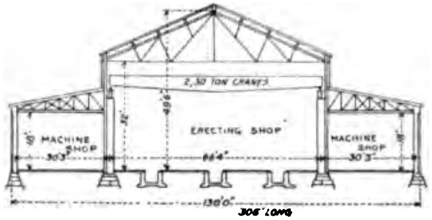

FIG. 71—CROSS SECTION OF MAIN LOCOMOTIVE SHOP, BOSTON AND MAINE, CONCORD.

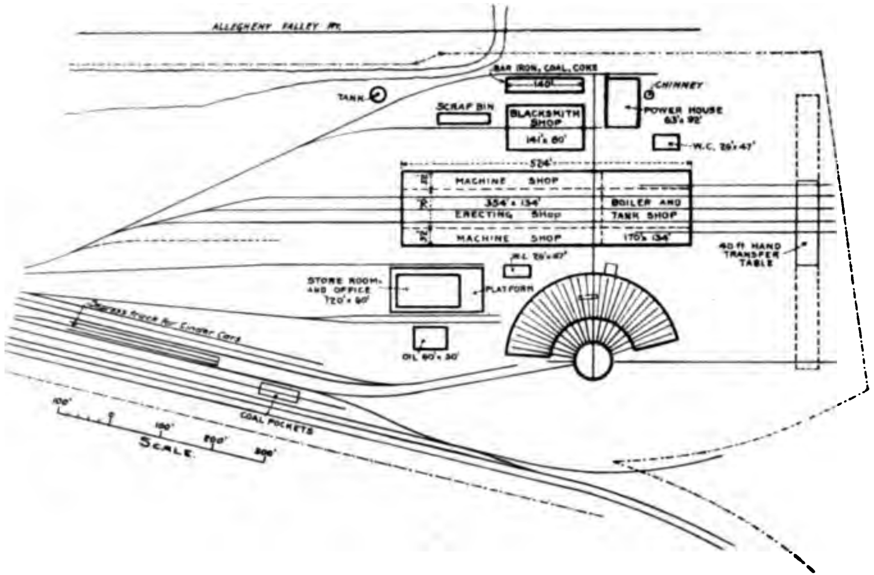

Fig 72—Locomotive Repair Shops, Buffalo, Rochester & Pittsburgh, Dubois, Pa.

Longitudinal locomotive erecting shop, capacity about 14 engines. New shops, 1901.

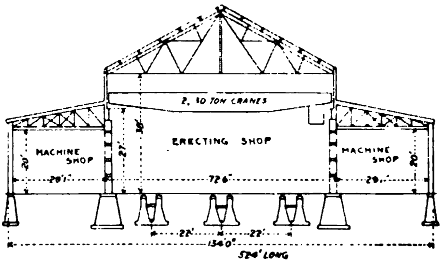

FIG. 73—CROSS SECTION OF MAIN LOCOMOTIVE SHOP, B. R. & P., DUBOIS.

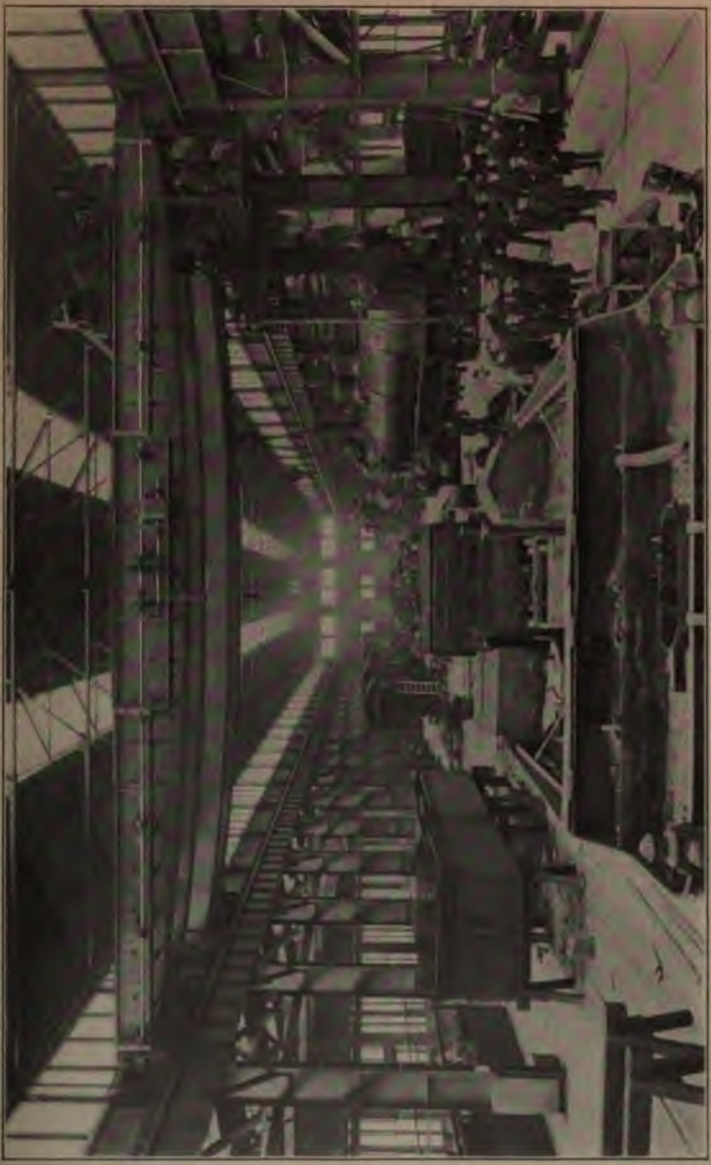

Fig. 74—Main Locomotive Shop, B., R. & P., Dubois.

Two 50-ton Shaw cranes in erecting shop.

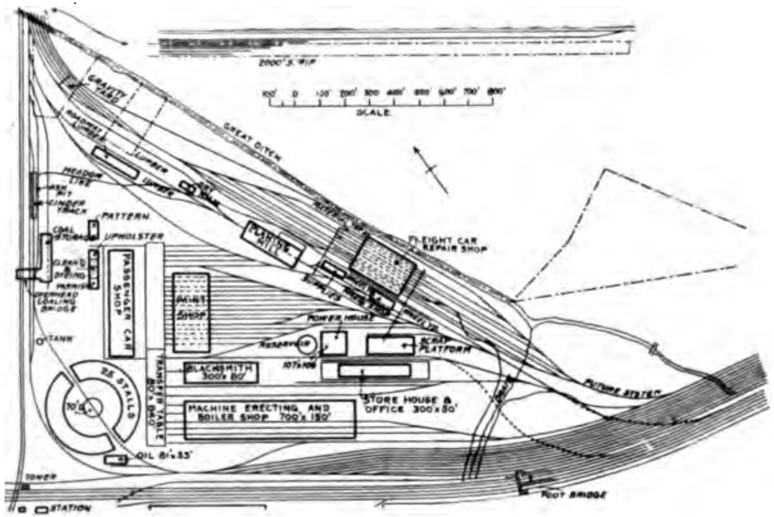

FIG. 75—GENERAL REPAIR SHOPS, CENTRAL OF NEW JERSEY, ELIZABETHPORT, N. J.

Longitudinal locomotive erecting shop, capacity about 20 engines. Transfer table passenger car shop. Longitudinal freight car shop. New shops, 1901.

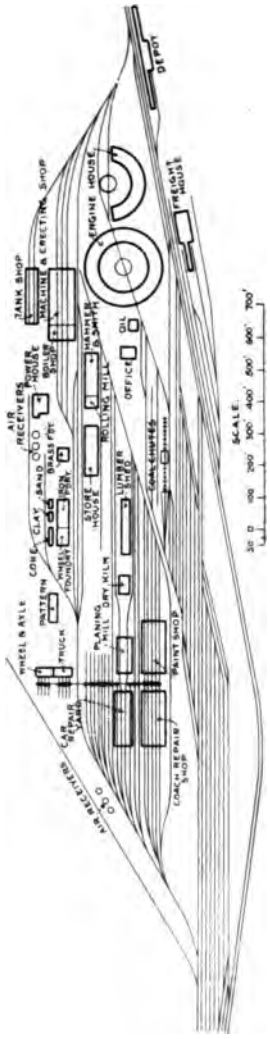

FIG. 76—GENERAL REPAIR SHOPS, MEXICAN CENTRAL, AGUAS CALIENTES, MEX.

All longitudinal layout. New shops, 1902.

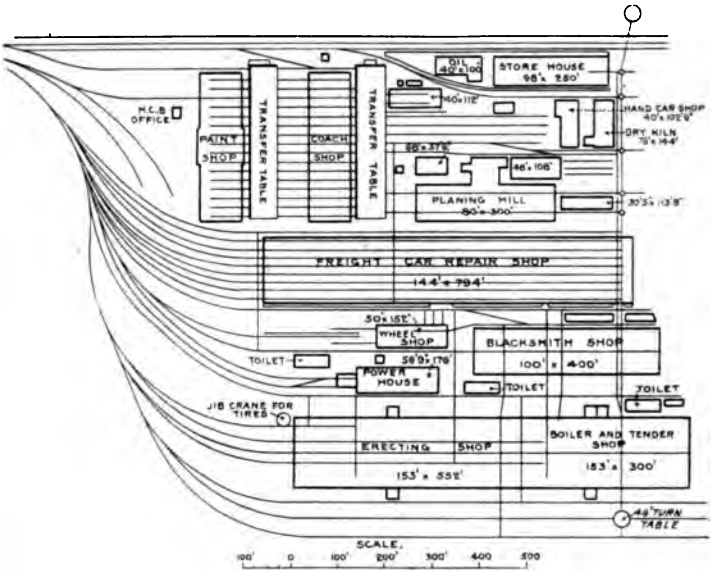

FIG. 77—GENERAL REPAIR SHOPS, ATCHISON, TOPEKA & SANTA FE, TOPEKA, KAN.

Longitudinal locomotive erecting shop, capacity about 24 engines. Transfer table passenger car shop. Longitudinal freight car shop. Old shops, extended, 1902.

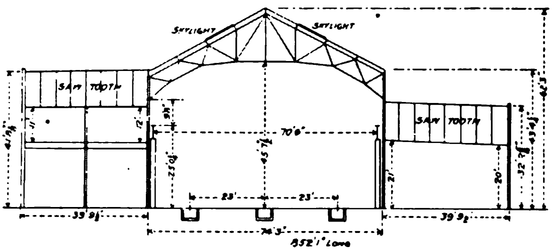

FIG. 78—CROSS SECTION OF MAIN LOCOMOTIVE SHOP, A., T. & S. F., TOPEKA.

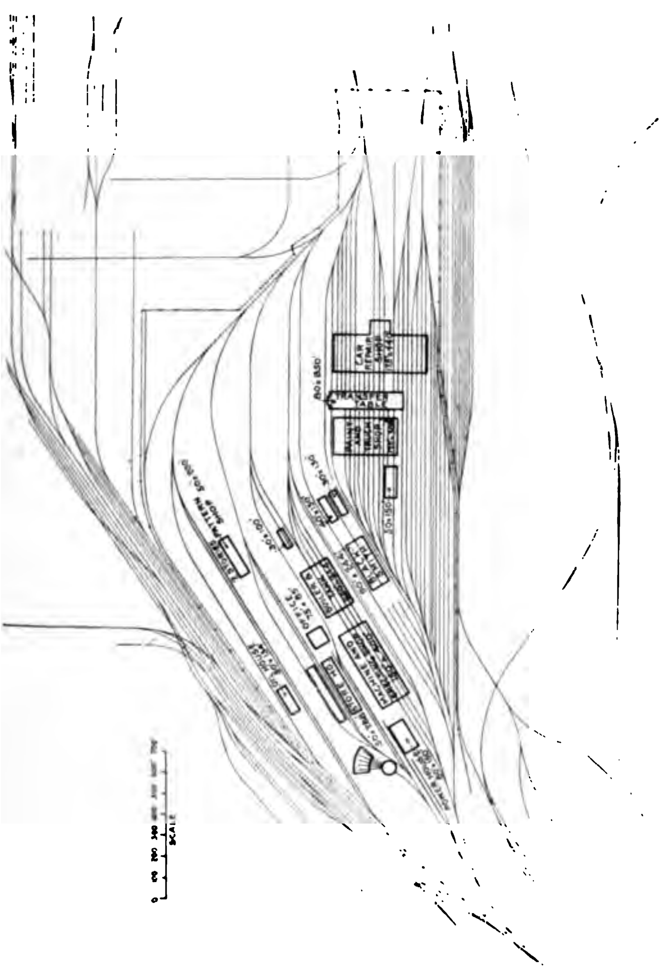

Fig. 79—General Repair Shops, Union Pacific, Omaha, Neb.
Longitudinal locomotive erecting shop, capacity about 18 engines. Transfer table combined passenger and freight car shop. Old shops, extended, 1902.

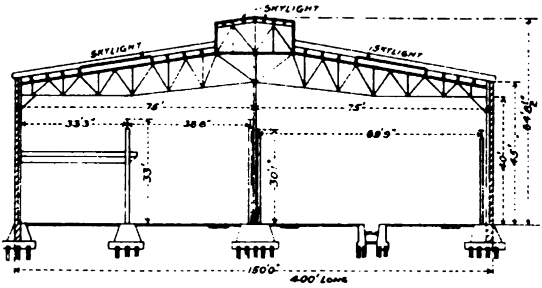

FIG. 80—CROSS SECTION OF MAIN LOCOMOTIVE SHOPS, UNION PACIFIC, OMAHA.

Fig. 81—Main Locomotive Shop, Union Pacific, Omaha.

Two 50-ton Niles cranes in erecting shop.

FIG. 82—MAIN LOCOMOTIVE SHOP, UNION PACIFIC, OMAHA.

10-ton Niles crane in machine shop.

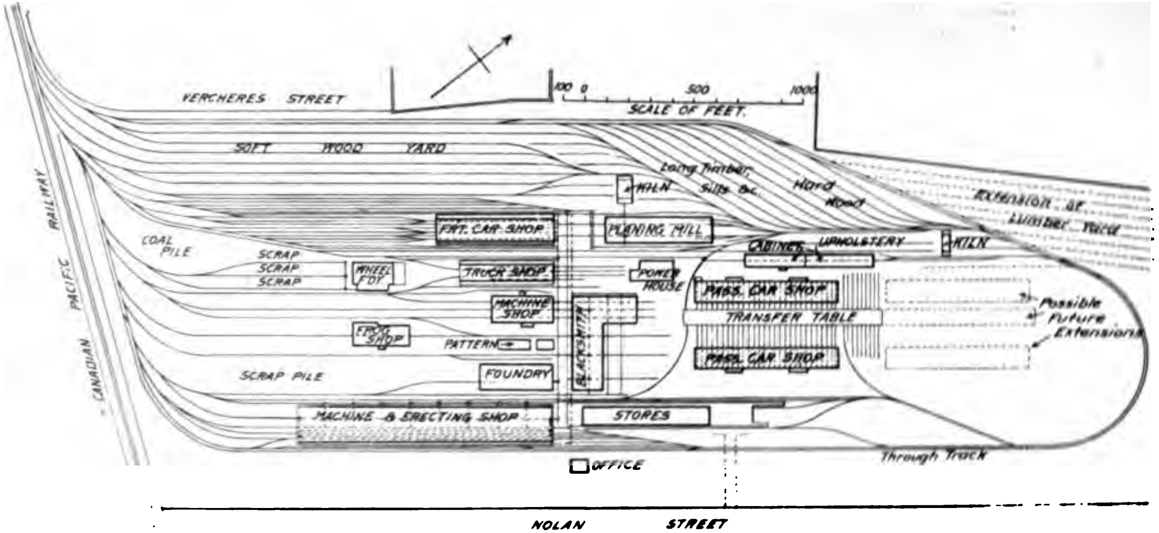

FIG. 83—GENERAL REPAIR SHOPS, CANADIAN PACIFIC, MONTREAL, CAN.

Longitudinal locomotive erecting shop, capacity about 42 engines. Transfer table passenger car shop. Longitudinal freight car shop. New shops, 1902.

Fig. 84—Locomotive Erecting Shop, Canadian Pacific, Montreal.

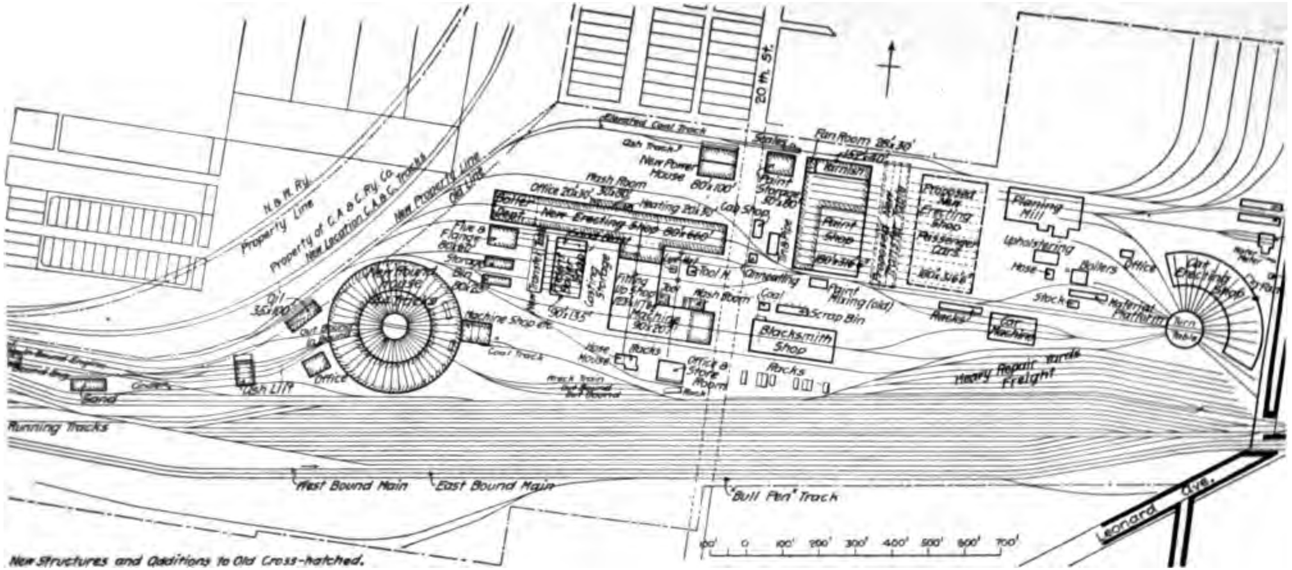

FIG. 85—GENERAL REPAIR SHOPS, PENNSYLVANIA LINES, SOUTHWEST SYSTEM, COLUMBUS, O.

Longitudinal locomotive erecting shop. Transfer table passenger car shop. Roundhouse freight car shop. Old shops, remodeled, 1902.

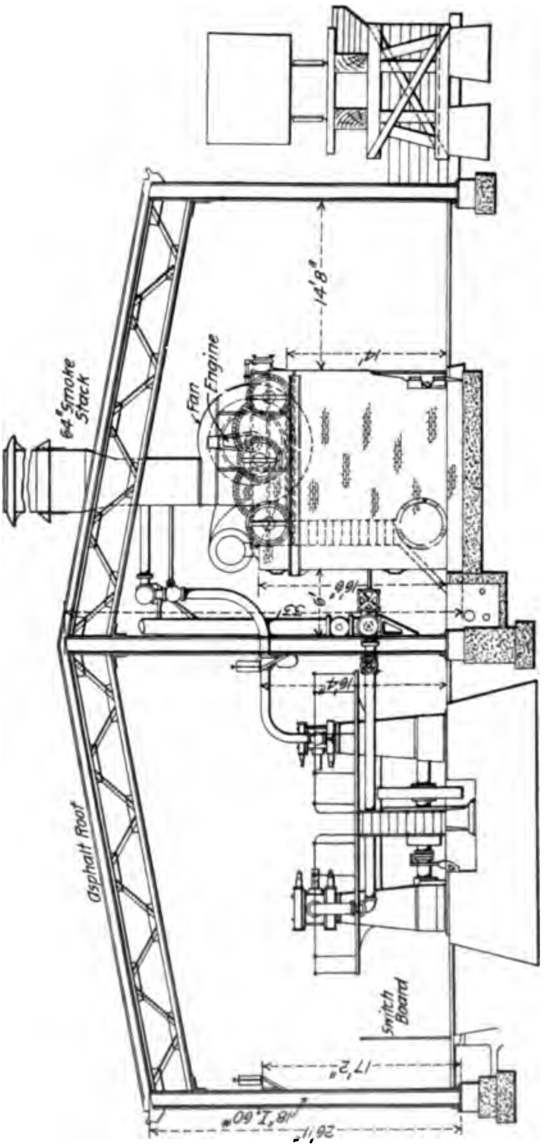

FIG. 86—CROSS SECTION OF POWER HOUSE, PENNA. LINES, COLUMBUS.

FIG. 87—MAIN LOCOMOTIVE SHOP, PENNA. LINES, COLUMBUS.

Two 75-ton Shaw cranes in erecting shop.

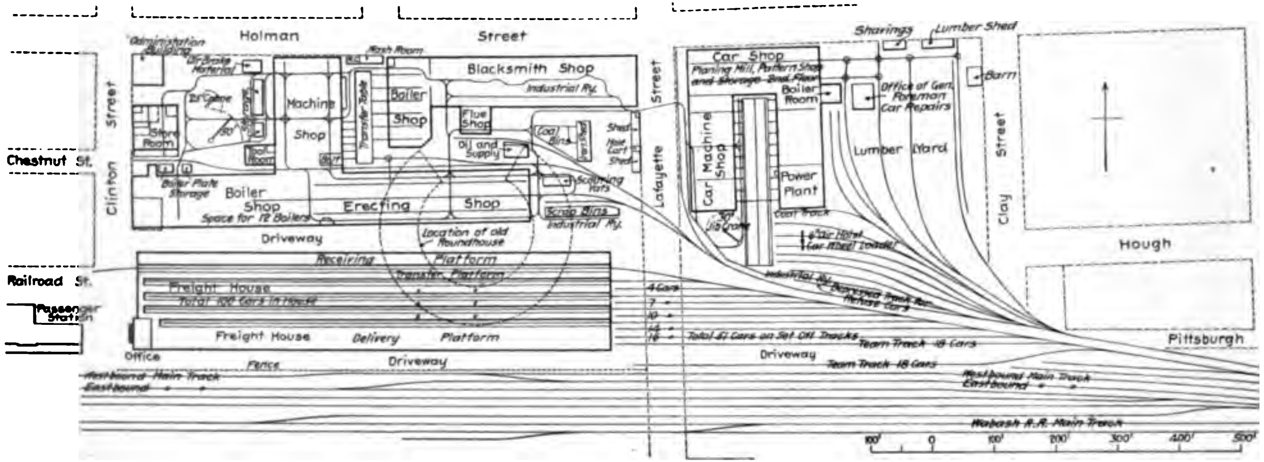

Fig. 88—Locomotive Repair Shops, Pennsylvania Lines, Northwest System, Fort Wayne, Ind.

Longitudinal locomotive erecting shop. Old shops, remodeled 1903, when new erecting shop built, as shown in illustration.

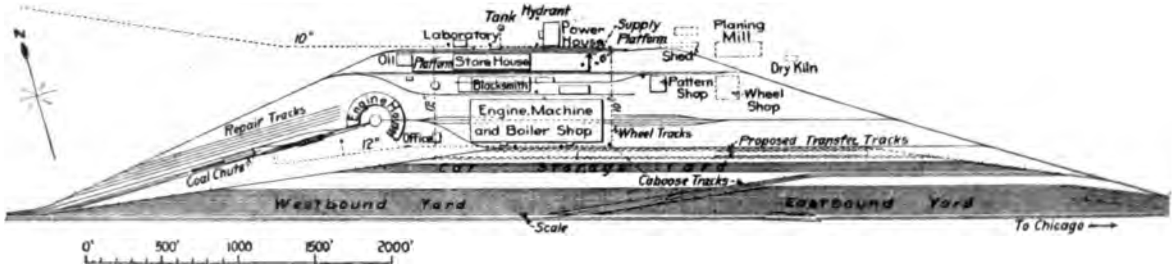

FIG. 89—LOCOMOTIVE REPAIR SHOPS, CHICAGO, ROCK ISLAND & PACIFIC, EAST MOLINE, ILL.

Longitudinal locomotive erecting shop, capacity about 44 engines. New shops, 1902.

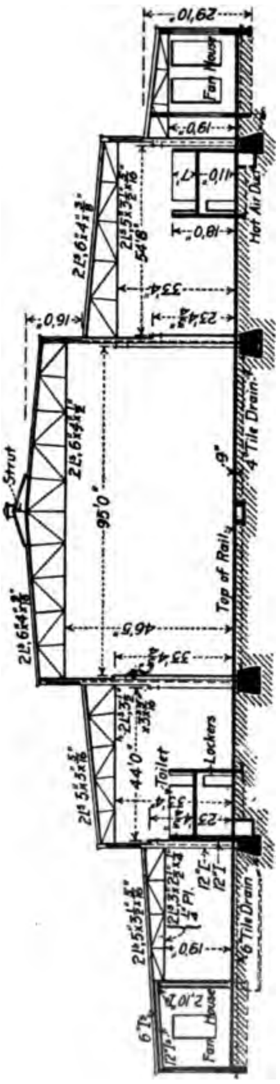

FIG. 90—CROSS SECTION OF MAIN LOCOMOTIVE SHOP, C., R. I. & P., EAST MOLINE.

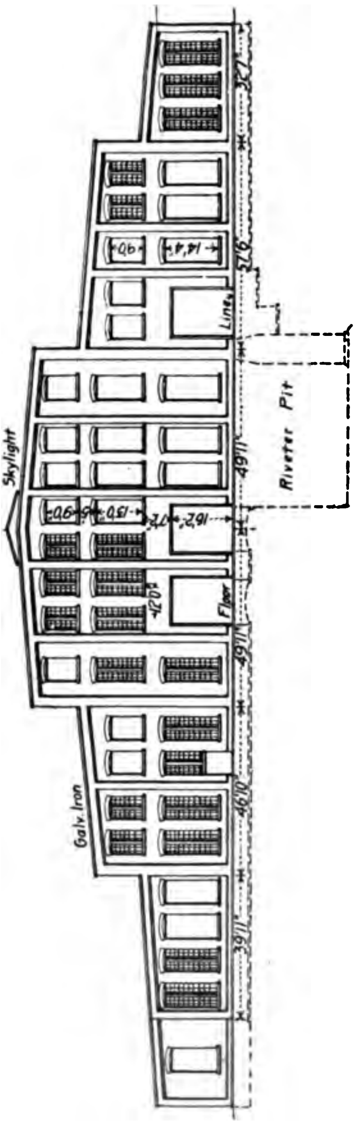

FIG. 91—END ELEVATION OF MAIN LOCOMOTIVE SHOP, C., R. I. & P., EAST MOLINE.

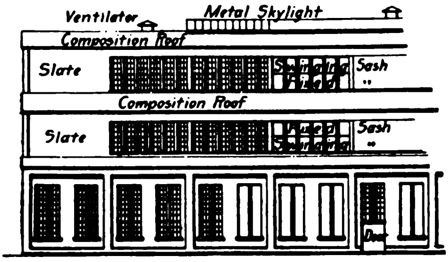

FIG. 92—SIDE ELEVATION OF MAIN LOCOMOTIVE SHOP, C., R. I. & P., EAST MOLINE.

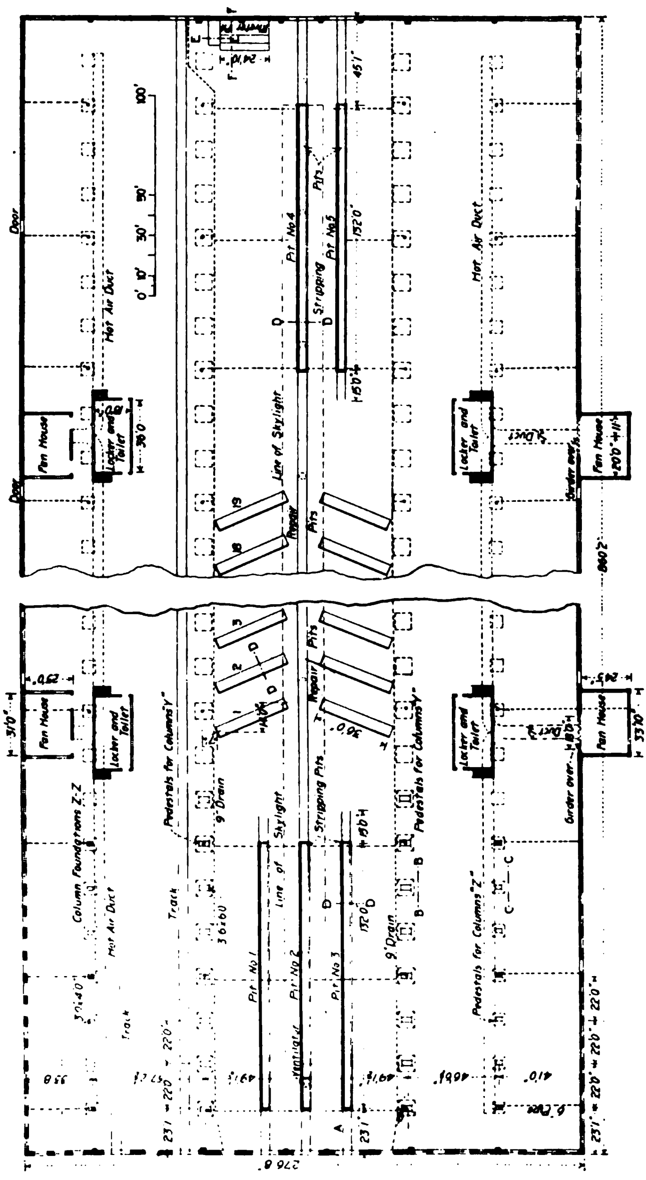

FIG. 93—PLAN OF MAIN LOCOMOTIVE SHOP (ERECTING, MACHINE AND BOILER SHOPS), C., R. I. & P., EAST MOLINE.

FIG. 94—MAIN LOCOMOTIVE SHOP, C., R. I. & P., EAST MOLINE.

Two 50-ton Shaw cranes in erecting shop.

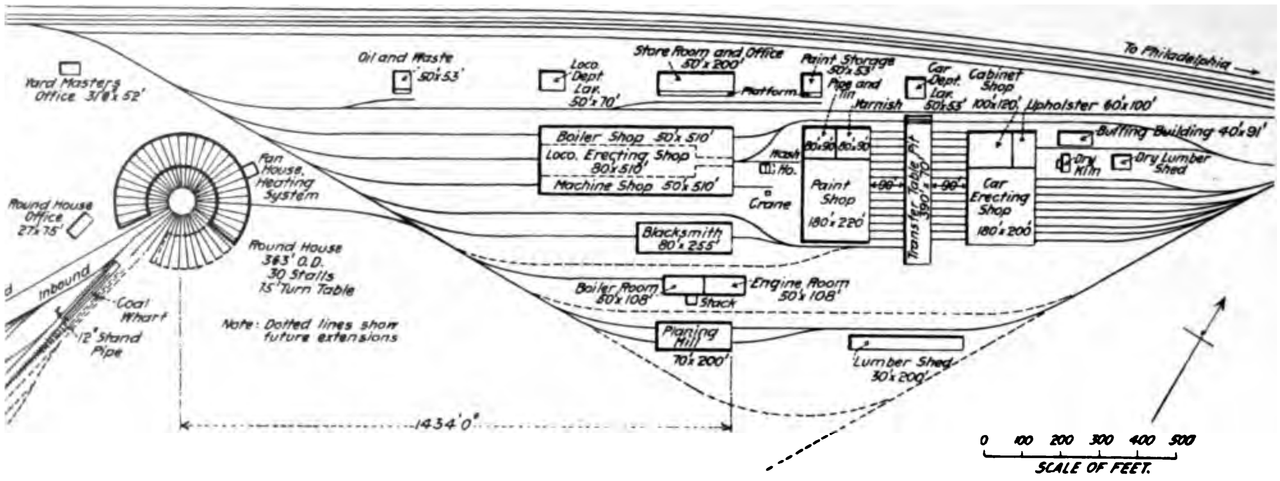

FIG. 95—GENERAL REPAIR SHOPS, PENNSYLVANIA (P., W. & B.), WILMINGTON, DEL.

Longitudinal locomotive erecting shop. Transfer table car shop. New shops, 1903.

Fig. 96—Locomotive Erecting Shop, Pennsylvania, Wilmington, Del.

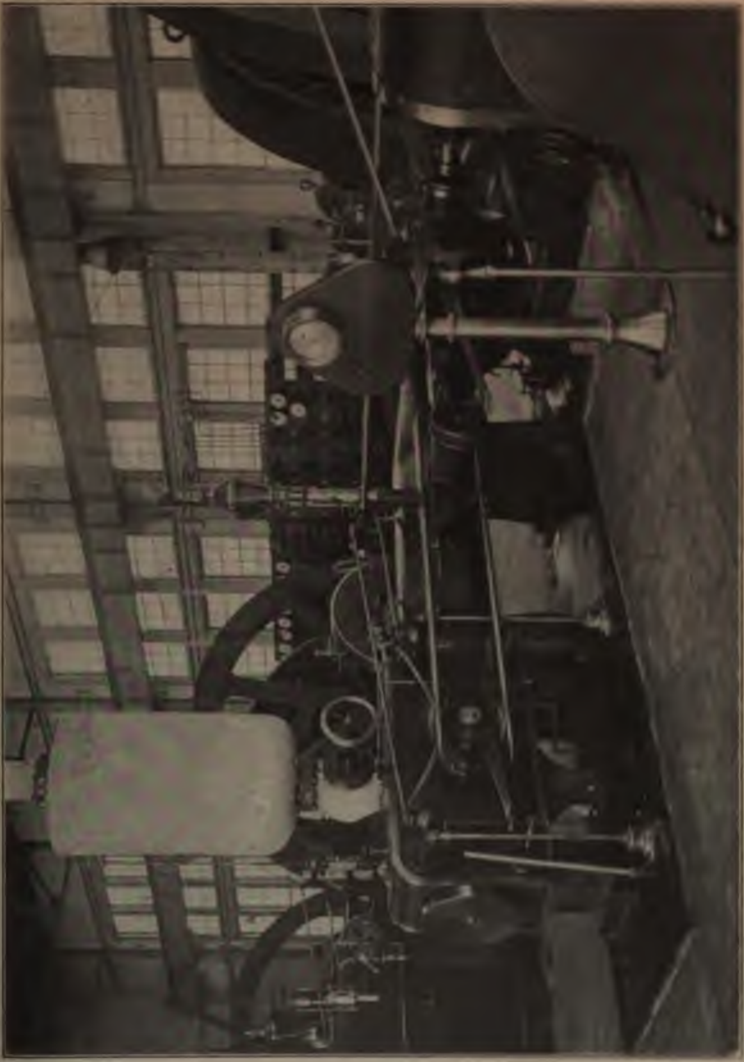

FIG. 97.—ENGINE ROOM, SHOP POWER PLANT, PENNSYLVANIA, WILMINGTON, DEL.

FIG. 98—MAIN SWITCHBOARD IN ENGINE ROOM, SHOP POWER PLANT, PENNSYLVANIA, WILMINGTON, DEL.

FIG. 99—STEAM PIPING IN BOILER ROOM, SHOP POWER PLANT, PENNSYLVANIA, WILMINGTON, DEL.

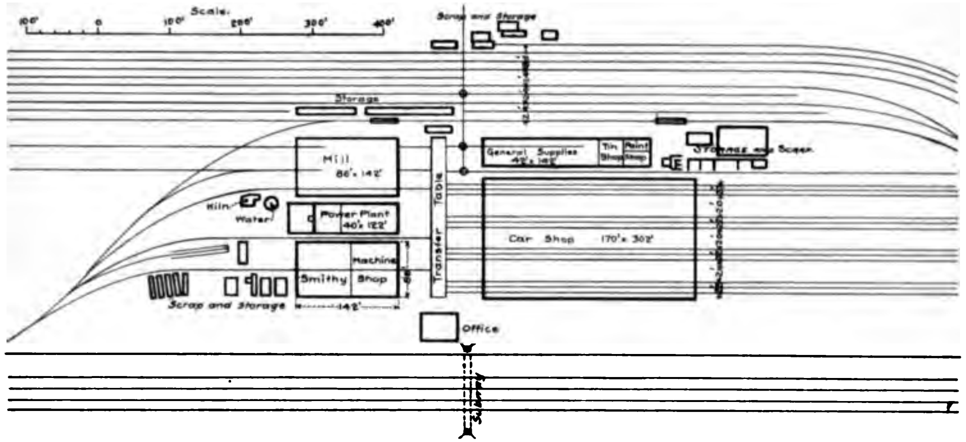

FIG. 100—FREIGHT CAR REPAIR SHOPS, MERCHANTS' DESPATCH COMPANY, ON LINE NEW YORK CENTRAL, AT DESPATCH, N. Y.

Longitudinal freight car shop with track approach at one end and transfer table at other end, serving all buildings. New shops, built in 1897 by Merchants' Despatch Company for repairs and building freight cars.

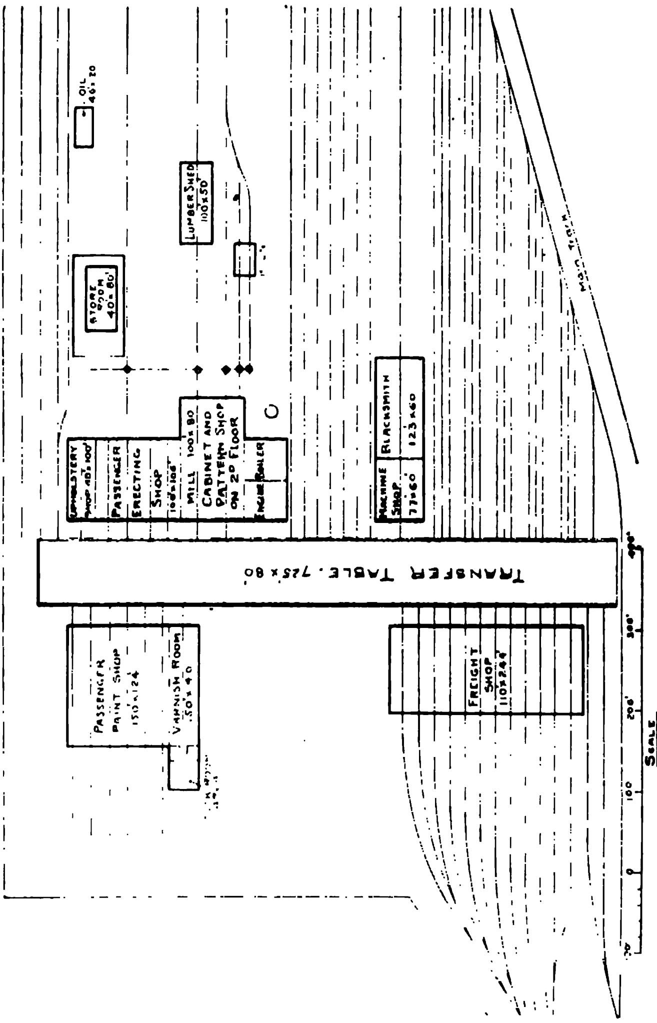

FIG. 101—MAIN CAR REPAIR SHOPS, MISSOURI, KANSAS & TEXAS, SEDALIA, MO.

One transfer table for passenger car shop and freight car shop. New shops. 1898.

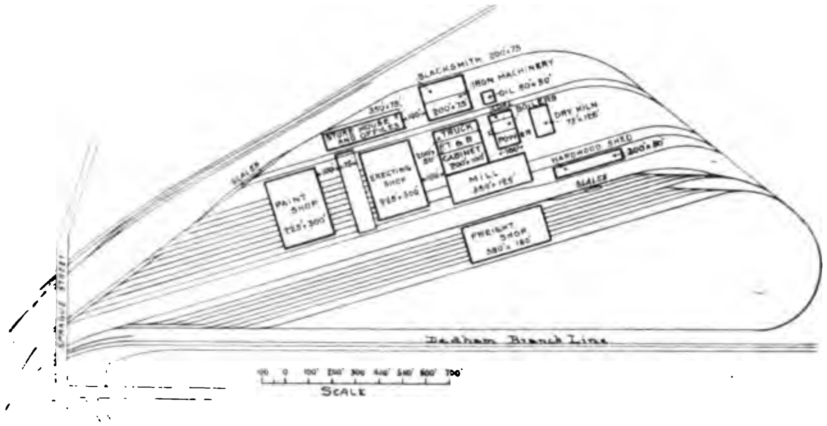

FIG. 102.—MAIN CAR REPAIR SHOPS, NEW YORK, NEW HAVEN & HARTFORD, READVILLE, MASS.

Transfer table passenger car shop. Longitudinal freight car shop. New shops. 1901.

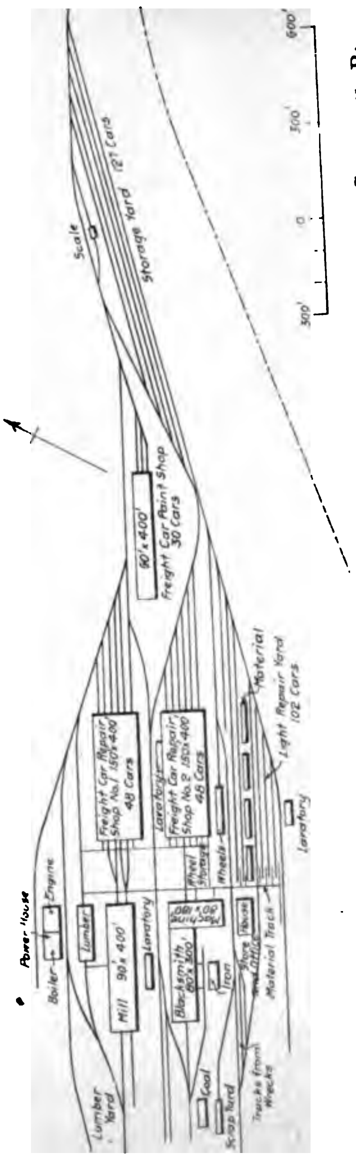

FIG. 103—MAIN FREIGHT CAR REPAIR SHOPS, DELAWARE, LACKAWANNA & WESTERN, SCRANTON, PA.

Longitudinal freight car shop with track approach. Mainly for coal car repairs. New shops. 1902.

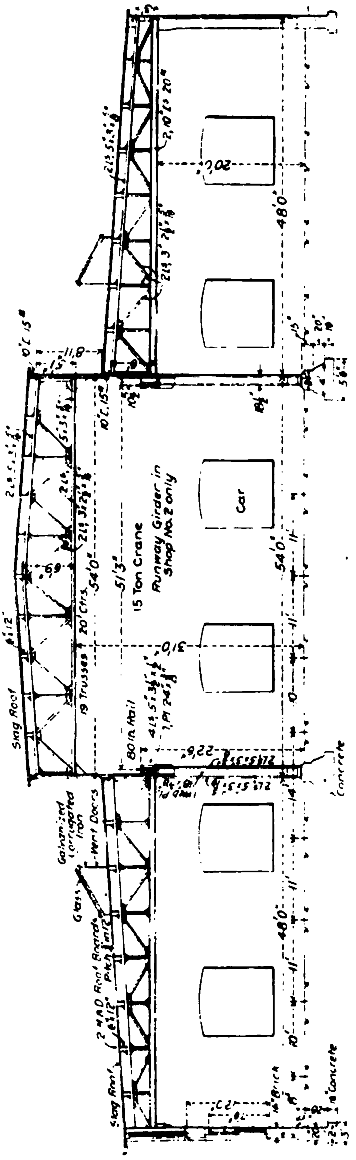

Fig. 104—Cross Section of Freight Car Repair Shop, D., L. & W., Scranton.

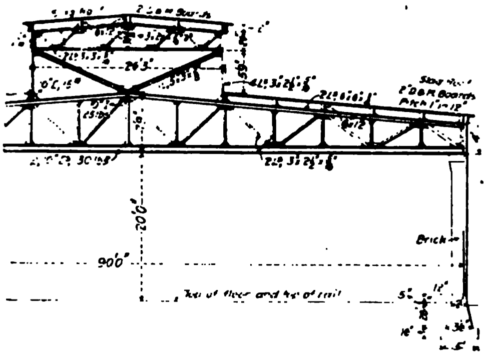

FIG. 105—CROSS SECTION OF CAR SHOP MILL, D., L. & W., SCRANTON.

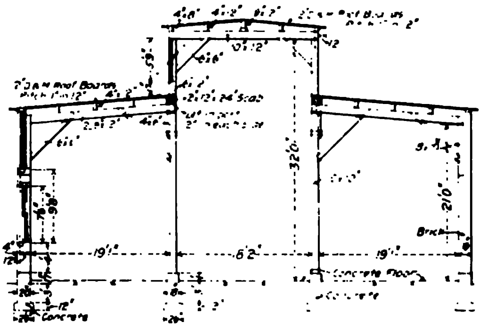

FIG. 106—CROSS SECTION OF PAINT SHOP, D., L. & W., SCRANTON.

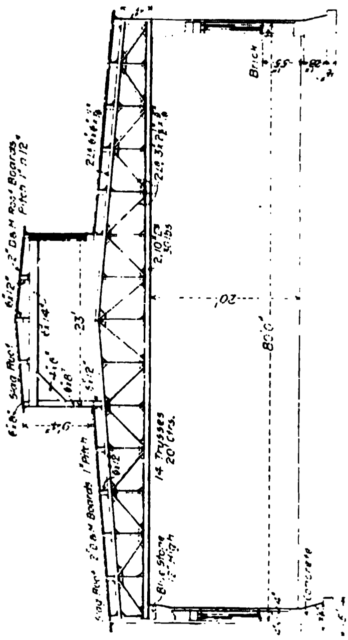

FIG. 107—CROSS SECTION OF BLACKSMITH SHOP, D., L. & W., SCRANTON.

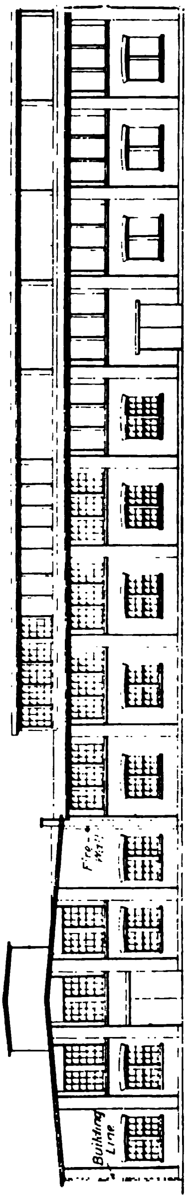

FIG. 108—ELEVATION OF MACHINE SHOP AND BLACKSMITH SHOP, D., L. & W., SCRANTON.